



# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

## **THESIS**

### **VIRTUAL ENVIRONMENT TRAINING ON MOBILE DEVICES**

by

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September 2013

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**VIRTUAL ENVIRONMENT TRAINING ON MOBILE DEVICES**

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## **ABSTRACT**

Over 100 million tablet computers have been sold in the last three years. They now have the computing power of a state-of-the-art laptop of just a few years ago. This computing power and market saturation allows them to become viable virtual environment (VE) trainers. Tablets have a different set of input modalities and user expectations, which need to be taken into careful consideration when a VE trainer is designed. The authors developed a VE call for fire (CFF) trainer and explored the processes necessary to make it successful. In order to utilize tablet hardware to its full potential, the authors devised the Window to the World (W2W) paradigm as it applies to a mobile device. The authors' tablet CFF trainer, Supporting Arms Trainer—Mobile (SAT-M), was compared to the Marine Corps' current laptop CFF system, ObserverSim. Despite being in early development, participants with and without CFF experience overwhelmingly preferred SAT-M ( $p=0.002$ ). Reasons included the ability of W2W to mimic real world physical motion, an easier to use interface, and a decrease in extraneous cognitive load.

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## LIST OF ACRONYMS AND ABBREVIATIONS

AO	Air officer
CAN	Combined arms network
CAS	Close air support
CFF	Call for fire
CFFT	Call for fire trainer
CLRF	Common laser range finder
COTS	Commercial off-the-shelf
GOTS	Government off-the-shelf
CTA	Cognitive task analysis
DAGR	Defense advanced GPS receiver
DoD	Department of Defense
DOS	Disk operating system
DVTE	Deployable virtual training environment
EWTPAC	Expeditionary warfare training group pacific
FDC	Fire direction center
FiST	Fire support team
FOC	Full operational capability
FOPCSim	Forward observer personal computer simulator
FOTS	Forward observer training simulator
FSCC	Fire support control center
GLTD	Ground laser target designator
GPS	Global positioning system
GUARDFIST II	Guard unit armory device full-crew interactive simulation trainer II
GUI	Graphical user interface
HARs	Human ability requirements
HE	High explosive
HE/MT	High explosive / mechanical time
HLA	High level architecture
HMD	Head mounted display

HOB	Height of burst
HSV	High speed vehicle
ICM	Improved conventional munitions
IOC	Initial operational capability
ISMT-E	Indoor simulated marksmanship trainer-enhanced
ITS	Individual training standards
ITX	Infantry training exercise
IZLID	Infrared zoom laser illuminator designator
JFETS	Joint fires and effects trainer system
JFO	Joint forward observer
JSAF	Joint semi-autonomous force
JTAC	Joint terminal attack controller
LTD	Laser target designator
MCAGCC	Marine Corps air ground combat center
MCCRES	Marine Corps combat readiness evaluation system
MCO	Marine Corps order
MEF	Marine expeditionary force
MiniTSFO	Miniature training set fire observation
MOVES	Modeling, virtual environments and simulation
MSAT	Multi-purpose supporting arms trainer
MTO	Message to observer
MVC	Model-view-controller
O&M	Operations and maintenance
OP	observation post
OT	Observer target
PC	Personal computer
PDSS	Post deployment software support
PEO-STRI	U.S. Army program executive office for simulation, training, & instrumentation
PLDR	Portable lightweight designator rangefinder
POSREP	Position report
RDT&E	Research development testing and evaluation

RFMSS	Range facility management support system
SAT-M	Supporting Arms Trainer-Mobile
SAVT	Supporting arms virtual trainer
SDS	Software delivery system
SME	Subject matter expert
SOP	Standard operating procedures
T&R	Training and readiness
T/O	Table of organization
TACP	Tactical air control party
TSFO	Training set fire observation
TTECG	Tactical training exercise control group
TTPs	Tactics techniques and procedures
UAV	Unmanned aerial vehicle
USMC	United States Marine Corps
VE	Virtual environment
W2W	Window to the world
WP	White phosphorus

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# **I. INTRODUCTION**

## **A. PROBLEM STATEMENT**

Military simulation training is not what it should be. It is often slow to adopt new technology. When innovations are adopted, frequently they are shoehorned into old paradigms, failing to maximize their advantages. This results in military simulation training that is not as effective as it could be, training opportunities are lost and expensive older simulators are run when a better cheaper option should be available.

In the beginning of 2010, the first mass produced touch screen tablet computers became commercially available. In less than three and a half years over 100 million have been sold (Associated Press, 2012). iPads released in the fall of 2012 have a 1.4 GHZ dual core processors (Shimpi, 2012), making them as powerful as laptops were just a few years earlier. It is often hard to tell when a technology is mature enough that it merits being adopted. The authors will demonstrate that tablet computers have achieved the necessary user base and maturity needed to become viable platforms for military virtual environment training.

Call for fire (CFF) is an ideal mission set for virtual environment (VE) training. There is a large demand signal for it in the Marine Corps, as most every Marine would benefit from some exposure to it. CFF is a perishable skill that requires frequent currency training. Additionally, live indirect fire training is both expensive and time consuming. VE training will never replace sending live rounds down range. However, it does greatly increase training opportunities and when used in conjunction with live fire training ensures that the training event is maximized.

To demonstrate the capacity and potential of ve training using the tablet platform, a call for fire (CFF) virtual environment (VE) training simulation was developed. We followed a process that emphasized the reuse of previous design

work performed to produce CFF VE simulations for desktop / laptop systems. The development path was tailored towards the unique features and capabilities of tablet systems. The authors felt it was paramount that advances in technology be incorporated into the design process. After a functional prototype was created, we devised an experiment that compared the tablet system to an existing desktop / laptop CFF VE training system. Due to time constraints the objective was not to make an exact copy of the desktop CFF simulator but to create a tablet simulator as a proof of concept.

The focus of this thesis is not on CFF training but on VE training on tablets. The authors show that it is possible to provide high quality VE training on a tablet and that there is a desire to have this capability in the fleet. We will also explore some of the strengths and weaknesses of tablet VE training using CFF as our vehicle.

## **B. MOTIVATION**

In the Marine Corps, there is an adage: “killing time kills Marines.” On any given day Marines spend a great deal of time waiting for the next training event or being transported from one place to another. To take advantage of this idle time, small unit leaders often have “hip pocket” classes that discuss pertinent tactics techniques and procedures (TTPs). The small unit leaders’ training fidelity is limited by the resources they have available. Situationally, expedient training methods such as throwing little rocks at bigger rocks to simulate CFF provides some instruction, but it does not provide the same quality as that received in a simulation-training center. Coordinating and executing joint forward observer (JFO) training in a simulation-training center is an option, but this requires a block of time that is not always available to a unit in a full pre-deployment training workup cycle. Existing simulation systems provide little opportunity for spontaneity or executing training in battalion spaces with high fidelity training systems. This situation is less than optimal, especially when considering the new era of fiscal constraint. In order to maintain proficiency, innovators within the



Department of Defense (DoD) must look towards easily distributed simulation as a viable alternative to live fire training (Deputy Commandant for Combat Development and Integration, 2012).

United States Marine Corps (USMC) *2012 Science and Technology Plan* identifies a critical training and education gap in training science and technology objective number six: Warrior simulation:

Marines need to train as they would fight as small units, particularly for dismounted operations. However, live training resources, facilities, ranges and training areas are limited. Simulation capabilities are needed to provide real-time effects and realistically engage the senses during challenging, rapidly reconfigurable scenarios to increase small units' opportunities to train when they do not have access to live resources. Develop capabilities to realistically simulate munitions (friendly and enemy) effects within live, virtual, and constructive training environments. Develop the ability to stimulate operational equipment used in live training environments from virtual or constructive environments, to improve the capability of simulations to augment and enhance live training opportunities and to reinforce realistic training using actual equipment as often as possible in conjunction with simulators and simulations. (Deputy Commandant for Combat Development and Integration, 2012)

Live fire training has always been constrained by the fiscal environment. History shows that military budgets ebb and flow in a relatively unpredictable manner (Walker, 2013). Current political and economic conditions indicate that DoD will be facing significant budget cuts (American Forces Press Service, 2013). These cuts will affect major acquisitions programs as well as every day unit operations and maintenance budgets. A reduction in funding creates fewer opportunities for required forward observer live fire proficiency training.

Even if budgets are unconstrained, operational tempo often limits a unit's ability to train. For example, over the last 10 years units in combat have been conducting operations that may not be in line with their primary mission (i.e., artillery units acting as provisional infantry) (Kroemer, 2006). During these combat tours there is little time or opportunity for the units to maintain their call

for fire skills. Upon completion of combat tours, where units are tasked to perform missions outside their primary skill sets, servicemen return with significant atrophy in their skills. Existing CFF training simulations include deployable options, which have been proven to adequately address cognitive skill retention in CFF tasks (McDonough & Strom, 2005). These deployable options have not been effective in addressing psychomotor and sensory perceptual categories of human ability requirements (HARs) assessment (McDonough & Strom, 2005).

One potential solution is to bring the simulation-training center to the service member. Supporting arms trainer-mobile (SAT-M) will be a suite of software programs that can be downloaded by the users to their personal tablet devices.

This research investigates the iterative process of training simulation development leveraging the rapid advances in commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) hardware as it progresses to desktop / laptops and finally evolves to mobile tablet systems. Personal computer (PC) based training has been previously validated for a variety of purposes; this study focuses on the differences required for tablet based simulation. We believe that by leveraging the native technology contained in most tablet devices, a one-to-one mapping between action in the real world and the virtual environment can be accomplished. For example, a user conducting virtual training on a tablet will have to turn his body around to survey his surroundings, much as he would in the real world. Figure 1 exemplifies the “window to the world” (W2W) concept which may add an additional element of realism by the very nature of the physical muscle movements that are required by the system.



Figure 1. Depiction of “window to the world” using SAT-M

When one adds a virtual environment with high fidelity graphics and sound, we believe it will deliver affordable, portable, and quality simulation training. Throughout this effort, we will strive to outline and define the way forward for future development in the area of realistic virtual training

### **C. RESEARCH QUESTIONS**

The work of Brannon and Villandre, 2002, provides evidence that CFF can be trained on a personal computer through the creation of forward observer personal computer simulator (FOPCSim) (Brannon & Villandre, 2002). Subsequent research investigated the training effectiveness of the system (McDonough & Strom, 2005). With rapid advances in technology, how can DoD best exploit these advances while simultaneously leveraging the existing proven bodies of work to provide virtual training that is both accessible and effective? Our work seeks to further previous investigations of virtual environment training.

This analysis provides a framework for the progression of virtual training over the spectrum of desktop, laptop, and mobile tablet PC devices. In the process we answer the following questions:

1. Is a VE trainer on a tablet possible?
2. Is the “Window to the world” paradigm seen as a valuable addition to VE training?
3. Would military officers trained in CFF see a value in VE tablet CFF training?
4. Would military officers untrained in CFF see a value in VE tablet CFF training?
5. What is gained and lost when CFF is executed on a tablet versus a desktop / laptop?
6. How does a VE tablet training program need to be different from a desktop / laptop VE training program?

#### **D. ORGANIZATION OF THE THESIS**

This thesis is organized in the following chapters:

Chapter I, introduction, an overview of the work contained in this thesis and the problem the authors are trying to solve.

Chapter II, background, provides a historical background on past and current Joint Forward Observer trainers.

Chapter III, task analysis, provides an analysis of the tasks than an individual performs as they execute a CFF and how those actions map to SAT-M.

Chapter IV, requirements, looks at the requirements for a tablet based VE CFF trainer. It specifically details how those requirements are different than the requirements for a desktop / laptop VE CFF trainer. It provides use cases for SAT-M and the two dominant Marine Corps CFF VE trainers. This chapter answers research questions five and six.

Chapter V, system development describes the process followed to create SAT-M.

Chapter VI, experiment outlines the methods and research process followed.

Chapter VII, results, answers research questions one through four.

Chapter VIII, conclusions, describes the authors' findings.

Chapter IX, future work, gives an overview of the way ahead for follow on research and development.

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## **II. BACKGROUND**

### **A. INTRODUCTION**

In 2010, Ben Brown conducted an in-depth review of simulation-training lineage, which he traced back to the very earliest versions of “serious games”. Examples of these early simulations include chess, Wei Ch’I, and Chaturanga. Brown’s discussion establishes the storied history of the relationship between simulations and military training (Brown, 2010). Since those days of yore the fidelity and range of applications of military simulation have improved and there is a direct link between these improvements and technology. Today’s technology makes it possible to train in a fully immersive virtual environment. The range, depth, and application of current military training simulations vary greatly. The background information contained in this thesis is limited to the investigation of simulation-training systems and technology specifically for the purpose of conducting call for fire procedural training.

### **B. CALL FOR FIRE PROCEDURE TRAINERS TIMELINE**

By its nature CFF training in a live fire environment is costly in terms of manpower, coordination and funding. CFF training simulation is needed to offset some of the constraints associated with live fire training. By using simulation Marines are able to train when resources are restricted.

Current and past CFF procedural training simulations fall into three broad categories: outdoor simulated firing ranges, indoor permanently fixed classroom facilities, and portable/deployable configurations. Each of these groups has distinct advantages and disadvantages.

Outdoor simulated firing ranges provide a robust experience that mimics the challenges of actual live fire; their primary disadvantage is that they are resource intensive. Indoor permanently fixed classroom facilities leverage dedicated computer resources and space to create fully integrated scenarios; however the facilities require coordination, scheduling, and reoccurring

maintenance. Portable / deployable simulations are found on laptop and portable devices, their greatest advantage is availability and convenience for the user, but without support staff they are only as good as the software running on them. The following are examples of these different CFF training technologies. They are listed in chronological order based on earliest found reference to their use in the DoD.

**1. M32 Sub-caliber Mortar Trainer, ca. 1960**

The M32 simulation utilized a CO<sub>2</sub> powered pneumatic sleeve inserted into an 81mm mortar tube. The device would fire a large 25mm training projectile onto a miniature range. This training device requires a significant amount of logistical support, including a large outdoor range area, instructor personnel who must establish a “to scale” range with maps, and extensive specialized equipment maintenance (Headquarters Department of the Army, 1960).

**2. M31 14.5 mm Field Artillery Trainer, ca. 1976**

The M31 simulation utilized a single fire rifle barreled assembly to simulate the fires of artillery. It required a miniature range with a special map. Designed for outdoor use the system was intended to be a low cost alternative for artillery units to train all of the personnel involved with call for fire conduct and execution. This system also required a robust support system to include the range setup, maintenance of equipment, and procurement of ammunition. This was not a simulation that lent itself to individual training proficiency. (Headquarters Department of the Army, 1976).

**3. Training set Fire Observation (TSFO), ca. 1982**

TSFO was a classroom artillery fire simulation where slides of terrain and weapons effects were projected onto a screen as seen in Figure 2. One of the first indoor simulated CFF trainers, it was used extensively for many years within DoD. The simulation required a large support system consisting of classroom



facilities, information technology services and contractor support (Headquarters Department of the Army, 1991). It is unknown if any of these systems are presently in use.



Figure 2. Photo of students using TSFO to practice CFF procedures (From United States Army Field Artillery School, 1989)

#### **4. MiniTSFO, ca. 1985**

MiniTSFO was a DOS-based PC simulation developed by Captain Bill Erwin as a research project that was then incorporated at West Point for cadet artillery fires training. The software is one of the earliest documented attempts to provide computer based CFF training (United States Army Field Artillery School, 1989).

#### **5. Indoor Simulated Marksmanship Trainer-Enhanced, ca. 1998**

ISMT-E is a marksmanship training simulation. It is normally installed in a permanent facility; using video projection the environment is displayed for the trainees to practice CFF procedures. It requires a trained operator and an instructor versed in CFF (if the operator is not). The ISMT uses actual equipment

integrated with the computer simulation for training. Personnel are also required to maintain and manage the equipment. (Program Manager Training Systems, 2013).

#### **6. Forward Observer Training Simulator, ca. 1998**

A computer based classroom training simulator, FOTS is primarily used by the Navy and Marine Corps for introductory school house CFF training. The system requires instructor support as well as facilities and personnel to maintain it (Naval Air Systems Command, Training Systems Division, 1998).

#### **7. Forward Observer Personal Computer Simulator, ca. 2002**

Created in 2002 by Brannon and Villandre as a MOVES Institute Master's thesis research project, the FOPCSim was originally intended to be prototype software that could fill the CFF training proficiency gap caused by limited resources. As live fire training is expensive, the idea at the time was to leverage improvements in computer technology to create a simulation robust enough to provide CFF procedure training for forward observers who were already qualified. It was originally developed for desktop computers. FOPCSim, see Figure 3, used a proprietary 3D game engine to run the simulation and the licensing costs were prohibitive to widespread fielding (Brannon & Villandre, 2002).



Figure 3. FOPCSim screen capture

#### 8. Joint Fires and Effects Trainer System, ca. 2003

JFETS is an immersive training simulation for the training and rehearsal of nearly all aspects of indirect fire control procedures. According to General Maples, the chief of field artillery in 2003, JFETS introduces highly realistic conditions and situations that add realism to the virtual environment. It is quite large and requires permanent facilities and contractor support (Maples, 2003).

#### 9. Guard Unit Armory Device Full-crew Interactive Simulation Trainer II, ca. 2003

This simulation provided CFF VE training by integrating the actual devices used by joint forward observers (JFOs) into the training scenario. GUARDFIST II was scalable from one to 30 trainees. It required classroom space, instructors, and maintenance personnel (U.S. Army Program Executive Office for Simulation, Training, & Instrumentation [PEO-STRI], 2003).

#### **10. Call for Fire Trainer, ca. 2005**

CFFT replaced GUARDFIST as the primary Army CFF simulation-training system. It is a classroom installed system that incorporates many of the tools used by joint forward observers. As many as 30 students can train on the system simultaneously. The design of the system necessitates a classroom environment with facilities and personnel (Mitchell, 2005).

#### **11. FOPCSim 2, ca. 2005**

FOPCSim 2 is a continuation of the research conducted at the MOVES institute by Brannon and Villandre. In 2005, McDonough and Strom extended the work of the original authors by creating a more robust version that was freely distributable to all Marines for personal use. This virtual environment CFF procedure trainer could be loaded on any Microsoft compatible personal computer. It ran on an open source engine, avoiding vendor lock in, thus making it free to distribute. FOPCSim 2 was widely used throughout the Marine Corps (McDonough & Strom, 2005).

#### **12. Deployable Virtual Training Environment, ca. 2005**

DVTE is a computer based simulation software suite that provides a multitude of virtual environment training options with the primary focus on combined arms Marine Air Ground Task Force integration and rehearsal training. Current revisions of this particular system include copies of FOPCSim as well as ObserverSim within the combined arms network (CAN) software package (DVTE Development Team, 2010). The intent of DVTE was to provide a deployable virtual training solution for Marine forces as a means to maintain proficiency in their skills while forward deployed. The software is maintained as a program of record within the Marine Corps and updates are provided annually via portable hard drives. This method of software maintenance requires the end-user to perform upgrades on the system, which implies that the receiving units must have some technological understanding and the time to upgrade the suite; no small task as one suite consists of 32 laptops (Grain, 2012).

### **13. Supporting Arms Virtual Trainer, ca. 2009**

The SAVT began as a non-program of record in the Marine Corps and Navy with the name Multi-purpose Supporting Arms Trainer (MSAT). In Figure 4 we see joint terminal attack controllers (JTAC) and JFOs training on SAVT utilizing its fully integrated real world equipment suite in an immersive virtual environment. The environment is projected onto a 15' high by 10' radius dome. This simulation system requires permanent facilities, maintenance, operators, and instructors (Bilbruck, 2009).



Figure 4. Marines using SAVT (From Bilbruck, 2009)

### **14. Observer Simulator, ca. 2010**

ObserverSim, included in the CAN software on DVTE, is the next iteration of FOPCSim. As stated in the *ObserverSim User's Guide*, "based on the original simulation created by the MOVES Institute of the Naval Postgraduate School" (DVTE Development Team, 2010). ObserverSim improves on the original design.

The above examples of virtual environment CFF procedure trainers are not meant to be all inclusive. There are many other examples of current technology either in use or in development. The Army Program Executive Office

for Simulation Training and Instrumentation 2013 catalog lists four simulations that could be used for CFF procedural training and rehearsal.

Presently, all virtual environment CFF procedure trainers fall within the spectrum of high-end large scale classroom facilities requiring significant additional resources, through deployable laptop based simulations, requiring a small degree of additional resources. Figure 5 depicts this concept, where the top of the diagram indicates CFF simulations requiring the highest amount of additional resources. Resources include maintenance, facilities, instructors, funds, and any other item required to run the simulation outside of the trainee themselves.

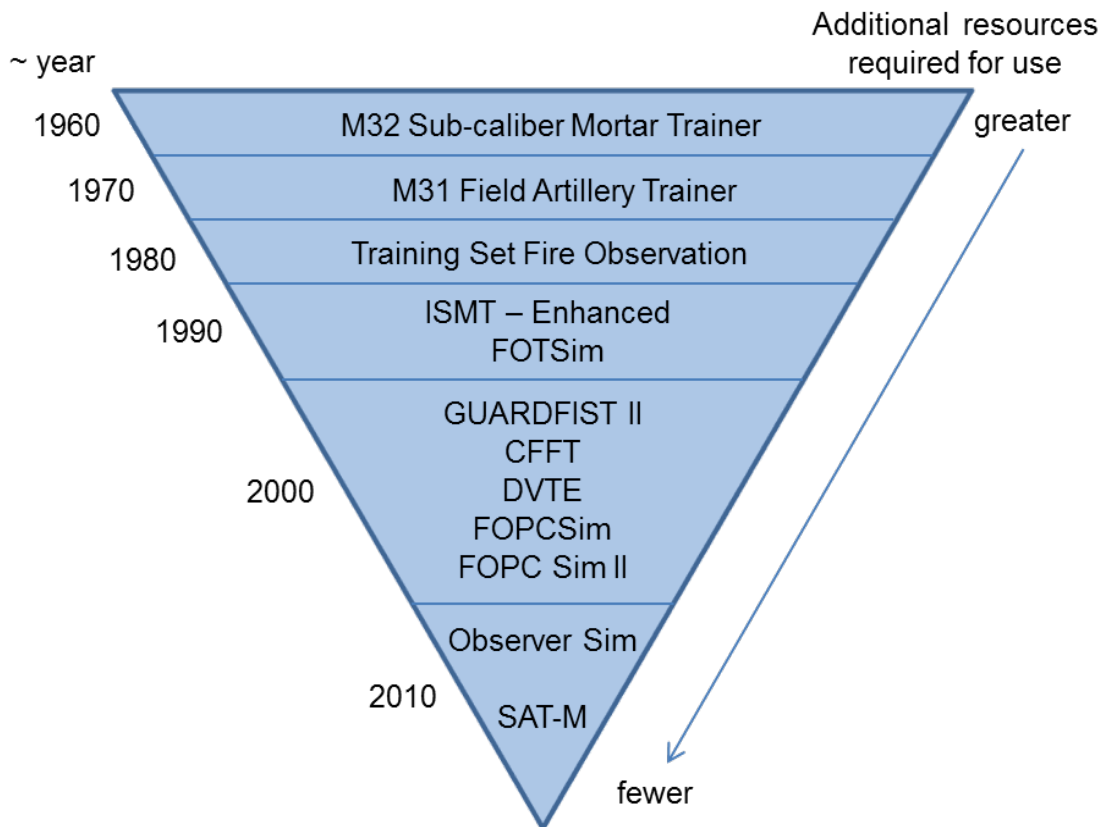


Figure 5. Simulator resource requirement over time

### **C. PREVIOUS WORK**

In 2002, David Brannon and Michael Villandre investigated the potential for a computer based CFF procedures trainer. Their efforts led to the development of FOPCSim. As previously described, FOPCSim was a proof of concept which showed a computer simulation could effectively reproduce the tasks required of a JFO. A thorough cognitive task analysis was conducted and the work established that many aspects of CFF procedure training can be trained inside a PC VE. After an experiment with the prototype software and experienced JFOs, “the results obtained indicate individuals trained in the forward observer task can use the FOPCSIM to maintain and improve proficiency for a skill set that is perishable without regular practice” (Brannon & Villandre, 2002). It is important to note that at the time the Marine Corps had few CFF VE resources available outside of the schoolhouse environment.

In 2005, James McDonough and Mark Strom conducted follow up work with FOPCSim. The research was intended to extend Brannon and Villandre’s previous work, transitioning FOPCSim from a prototype to a complete simulation that could run on existing computer equipment already in Marine Corps’ inventory. McDonough and Strom began with the cognitive task analysis conducted by Brannon and Villandre, then applied a human ability requirements assessment to determine the degree to which FOPCSim tasks map to the execution of the real world task. They found 27 skills required to complete basic CFF in the real world: 12 cognitive tasks, 10 sensory-perceptual, three psychomotor, and two that require special knowledge or skill. During further analysis, it was determined that cognitive tasks matched well between simulation and the real world, however psychomotor and sensory-perception related tasks did not. Subsequently, software was developed and then tested. Based on the results of this experiment McDonough and Strom determined that FOPCSim, when used as a training tool performed as well as, and in some cases better than, the legacy training method used in the control group (2005).

A significant finding of this work showed that a VE training simulation could be used to maintain certain perishable skills. Both sets of researchers identified a training shortfall resulting from the lack of available simulation capability. Their proposed solutions and designs were based on the technologies of their times.



### **III. TASK ANALYSIS**

Our task analysis begins where McDonough and Strom's ended in 2005. As previously discussed, they conducted a HARs absence presence assessment as part of their research. Their assessment revealed that psychomotor and sensory perceptual tasks are not well replicated within a desktop / laptop VE CFF simulation (McDonough & Strom, 2005).

A HARs assessment compares the execution of a real world task to the execution of that task in a VE. The HARs assessment tool was developed in 2003 by Cockayne and Darken. It is summarized by the following quote:

The chapter begins with a discussion of taxonomic science and classification as related to the development of the Human Ability Requirements (HARs) taxonomy for human performance evaluation. It discusses the extension of real-world taxonomy method and tools into VEs and how these can be used to extend and complement conventional task analyses. It is the linking of human abilities as required by task components to interaction techniques and devices that is of concern. Our research was based on the need to understand how humans perform physical tasks in the real world in order to guide the design and implementation of interaction techniques and devices to support these tasks in VEs. (Cockayne & Darken, 2003)

As desktop PCs typically use a mouse and a keyboard as the primary human computer interface and tablet devices use a multi-touch touchscreen in conjunction with accelerometers and gyroscopes as the primary human interface, comparing the two systems based on input modalities is nontrivial. A HARs assessment creates a framework that allows for the comparison of the two. The difference in input modalities, particularly as they relate to simulated training tasks, is the focus for our investigation.

## A. HUMAN ABILITY REQUIREMENTS REVIEW

In 2005, McDonough and Strom used the HARs taxonomy to identify 27 skills required to perform CFF tasks. Of the 27 skills, 12 were identified as cognitive skills and are listed in the top portion of Table 1.

Cognitive skills	
Oral comprehension	Deductive reasoning
Oral expression	Information ordering
Memorization	Spatial orientation
Problem sensitivity	Visualization
Mathematical reasoning	Perceptual speed
Number faculty	Time sharing
Specific knowledge / skills	
Map reading	Electronic knowledge

Table 1. Cognitive and specific knowledge / skills needed to perform CFF tasks  
(After McDonough & Strom, 2005)

After their analysis, which is detailed on page 20 of *The Forward Observer Personal Computer Simulator (FOPCSIM) 2*, they concluded that the FOPCSim software simulated CFF tasks as related to cognitive and specific knowledge / skills mapped well to the actual real world CFF tasks that require cognitive abilities and specific knowledge / skills. The results supported similar findings by Brannon and Villandre, who in 2002 concluded that:

... the FOPCSim user must perform the same steps to determine target location and formulate the call for fire as they would in the real world. FOPCSim maintains cognitive fidelity to the real task, but sacrifices physical fidelity. The performance differences are due to the physical interface and not the cognitive element. (Brannon & Villandre, 2002)

These results establish that CFF cognitive tasks can be effectively incorporated into a training simulation. Both previous versions of this software were developed for, and ran on, desktop or laptop devices that were typical of that period. In 2005, the year McDonough and Strom developed FOPCSim 2, Apple released the PowerBook G4, a laptop with 1.67 GHz G4 processor and 512 MB of RAM (Norr, 2006). In late 2012 Apple released the 4<sup>th</sup> generation iPad, which shipped

with a 1.4 GHz dual core A6X processor, and 1 GB of RAM, making the tablet as least as powerful as the PowerBook G4 (Shimpi, 2012). If it was possible to create a CFF VE training simulation that runs on the PowerBook G4, then it is certainly possible to create one that will run on the current generation of tablet computers. Therefore, we conclude that the cognitive component of the CFF VE can continue to be replicated on modern tablet computers while maintaining the same level of training efficacy.

The psychomotor and sensory perceptual skills required to conduct CFF, as identified by McDonough and Strom, are listed in Table 2.

Sensory / perceptual	
Near vision	Hearing sensitivity
Far vision	Auditory attention
Night vision	Sound localization
Depth perception	Speech recognition
Glare sensitivity	Speech clarity
Psychomotor	
Control precision	Arm / hand steadiness
Reaction time	

Table 2. Psychomotor and sensory perceptual abilities needed to perform CFF tasks (After McDonough & Strom, 2005)

Sensory / perceptual abilities are particularly difficult to replicate in a VE. For instance, we can simulate a night environment on a display, but unless the simulator is blacked out, it does not exercise true night vision. The illusion of distant objects can be easily simulated in a VE using 3D rendering techniques; however this simulation of a distant object does not actually require the use of a human's far vision ability. Other sensory / perceptual abilities that present unique challenges to a VE simulation include hearing sensitivity, sound localization, speech recognition, and speech clarity. The aforementioned abilities can be effectively recreated in a VE with special equipment and simulator configuration. However, our research is limited to desktop / laptop and tablet devices and the simulation of most sensory / perceptual abilities is outside the capabilities of the hardware.

We were able to narrow the field of human abilities as they relate to simulated task mapping differences between desktop / laptop systems and tablet systems by focusing on psychomotor tasks. Our analysis focuses on the modality differences between desktop / laptop and tablet systems, and their ability to train psychomotor skills. Tablet devices have a unique input control methodology, using accelerometers and gyroscopes to capture movement. A VE can use this input control methodology to change perspective, which maps to how a human being observes the real world. The software simulations used in our analysis are oriented from a first person perspective. With the tablet system the user must physically move their body, head, and eyes in order to change their view in the VE. In the desktop / laptop system the user's head and eyes are always looking forward at the stationary monitor and movements of the mouse control changes in perspective. W2W, the authors' concept for VE, utilizes the strength of the tablet system: the VE is all around the user, not locked in a stationary monitor.

Only those factors which diverge due to hardware differences between desktop / laptop and tablet systems were included in our analysis. These were determined by narrowing and validating the scope of the HARs absence / presence assessment. The psychomotor skills area had the greatest divergence and these were mapped by McDonough and Strom to Brannon and Villandre's cognitive task analysis, listed in Table 3.

CFF Human Ability Requirements assessment		Absence / Presence Test	
Comparison		Human abilities	
		<div>control precision</div> <div>reaction time</div> <div>arm/ hand steadiness</div>	
Call for Fire Task Analysis (Tasks)			
1.1.1 Utilize GPS.	x		x
1.1.2 Utilize Map and Compass.			x
1.1.3 Utilize available tanks sights or laser range equipment for resection.	m		m
3.2.3.2 Polar/Laser Polar			x
3.2.3.3 Shift from Known Point:			x
3.2.6 Send-Method of Fire and Control:	m		
3.2.12 Conduct-Spottings:		m	x
3.2.12.1 Height of Burst		m	x
3.2.12.2 Range		m	x
3.2.12.3 Deviation		m	x
modeled in real world not in FOPCSim		x	
modeled in both		m	

Table 3. HARs comparison between real world and FOPCSim (After McDonough & Strom, 2005)

Table 3 only displays the task to ability mapping for psychomotor skills when the comparison chart in McDonough and Strom indicates there is a match for the task in the simulation or real world. Non-psychomotor tasks are excluded from the table. Using the same process the tablet system was compared with human abilities (Table 4).

CFF Human Ability Requirements assessment		Absence / Presence Test		
Comparison		Human abilities		
Call for Fire Task Analysis (Tasks)				
1.1.1 Utilize GPS.	m			m
1.1.2 Utilize Map and Compass.				m
1.1.3 Utilize available tanks sights or laser range equipment for resection.	m			m
3.2.3.2 Polar/Laser Polar				m
3.2.3.3 Shift from Known Point:				m
3.2.6 Send-Method of Fire and Control:	m			
3.2.12 Conduct-Spottings:			m	m
3.2.12.1 Height of Burst			m	m
3.2.12.2 Range			m	m
3.2.12.3 Deviation			m	m
modeled in real world and not in a tablet system		x		
modeled in both		m		

Table 4. HARs comparison between real world and a CFF tablet system (After McDonough & Strom, 2005)

In Table 4, all CFF tasks that required psychomotor skills in the real world have a higher mapping to the task executed in simulation when a tablet system is used for CFF VE training. This supports and is explained through the unique input technology (accelerometers/ gyroscopes) and W2W, rotating the device itself as a window into the VE. All of the CFF tasks identified are highly dependent on psychomotor skills in the real world and the tablet can replicate these skills in a manner that is nearly analogous to real world action.

## B. COGNITIVE TASK ANALYSIS

During their previous investigation Brannon and Villandre completed a thorough cognitive task analysis which can be found in *The Forward Observer Personal Computer Simulator (FOPCSIM)*, chapter III. They conducted their analysis using the goals, operators, methods, and selection rules (GOMS) model. The source for their CTA was *Field Manual (FM) 6–30, Tactics, Techniques, and Procedures for Observed Fire*. FM 6–30 was superseded by *Army Technical Publication (ATP) 3–09.30 Techniques for Observed Fire* in August, 2013. We

complete a cross walk of the CFF tasks in the two publications to ensure that there have not been any significant revisions which would alter the previous task analysis or the HARs assessment. This comparison was limited to those tasks requiring psychomotor abilities as we have previously established that the remaining human abilities can be easily replicated (cognitive and specific knowledge / skills) or require special equipment (sensory / perceptual). The authors' review of the FM 6–30 and ATP 3–09.30 revealed that the revisions to CFF publication did not change the basic tasks required of a JFO. In particular we can validate that a JFO must still have the basic skills to determine self-location (via GPS or map and compass), target location (via target designation device or map study, and understanding of the required elements of the CFF brief. Therefore the CTA performed by Brannon and Villandre is still valid for the purposes of studying CFF procedures on a tablet system.

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## **IV. REQUIREMENTS**

### **A. OVERVIEW**

Before the requirements for SAT-M can be derived there needs to be an understanding of how it fits into the overall CFF simulation-training continuum. As discussed in Chapter II, currently the two most commonly used CFF simulators in the USMC are the SAVT and the software suite on the DVTE. In order to place the simulators within a greater context, use cases for the three systems are presented. These demonstrate the niches that each of the three simulators fill. Only once the niche for SAT-M is understood can the requirements be derived. It is important to remember that the requirements are being driven not only by the needs of the software to provide certain fidelity and functionality but also by the user's expectations of and the limitations and capabilities of tablet systems.

### **B. USE CASE SCENARIOS AND SYSTEM CHARACTERSTICS**

#### **1. SAT-M**

##### ***a. Case 1***

12th Marine Regiment has just departed Okinawa heading to Camp Fuji Combined Arms Training Center to execute artillery training. They embarked on the high speed vehicle (HSV) and the trip will take over 24 hours. While on the HSV the artillery liaison officer brings together the JFOs to conduct CFF training. A few on the JFOs have tablet computers, which have previously been loaded with SAT-M. During next few hours the artillery liaison officer conducts high quality VE CFF training, utilizing what otherwise might have been dead time. Before they embarking on the HSV, to ensure they have the most current build of SAT-M, all the tablets were connected to the internet to download any updates.

During the training the artillery liaison officer maintains his tablet in "instructor mode." This allows him to observe what the JFOs are doing in real-time and dynamically adapt the scenario based on the JFOs' performances,

increasing or decrease difficulty as appropriate. He is also able to recall their past missions to look for trends, allowing him to focus the training on those areas the JFOs find most difficult.

***b. Case 2***

Corporal Doe has been selected by his battalion to go to the JFO Course. In preparation for the course he has taken the MarineNet classes on CFF, received face-to-face instruction from one of the battalion's JTACs, and downloaded SAT-M onto his roommate's tablet. In the evenings he spends a few minutes in his barracks running through CFF scenarios, building an understanding of the fundamentals of CFF. He does not always train alone as a fellow squad mate has also been selected for the course. They often link their tablets via Bluetooth and train together in the same virtual environment.

**2. Characteristics of SAT-M and tablets**

***a. User Expectations***

It is important to note that user's expectations differ when using tablets or desktops / laptops. This encompasses the obvious (smaller screens, lighter weight and no keyboard) to the less obvious: software that is easy to use, the simplicity of interconnecting devices, use of the "cloud" for distribution and data storage. When running a tablet application users expect that a reference manual will not be needed. A button's function will be expressed through its icon and the user will not be lost in layers of menus. It is also expected that tablets will seamlessly enter a network; there is no need for setting IP address and subnet masks.

***b. Device Input***

Tablets are meant to be used on the go and as such have additional hardware not found in desktops or laptops. The current generation of tablets has built in GPS, accelerometers, gyroscope and in some cases a magnetic compass. They also come with microphones, speakers, cameras, and

of course multi-touch enabled touchscreens. This allows entirely new paradigms for interacting with the device. While SAT-M does not take a revolutionary approach to the user-device interface; it does try to take advantage of some of these inputs. Physically moving the tablet to change ones view, as described in the W2W, is one way. Modern tablet multi-touch enabled touchscreens allow for parallel inputs, more than one icon can be activated at a time. A mouse allows interaction with only one icon, resulting in serial inputs. There are some workarounds with keyboard shortcuts, but they are in general unwieldy. Real world devices follow a parallel input paradigm.

### ***c. Limitations and feedback***

With the exception of sharing media content, tablets are designed for individual use. Combined with W2W, it would be very hard for an instructor to evaluate the performance of more than a few individuals. Device portability also creates the expectation that it can be used without an instructor. It is therefore critical that the system be able to provide useful feedback; feedback of the sort that extends beyond reporting number of corrections, round accuracy, and mission execution time.

With a small screen a tablet device is not an ideal platform to conduct mission planning. However, doing so allows the software to extrapolate far more about user thought process and skill level than if just the CFF mission is executed on it. For example, the device will know user accuracy in plotting their position and the target's location. Useful feedback can then be provided using tablet-specific hardware and software: Was the user looking at the target when the rounds impacted? Did the user double check their position on the map, or just report their position straight from the defense advanced GPS receiver (DAGR)?

### ***d. Centralized Distribution***

The Apple App Store and Android Market have set the precedence for software distribution on mobile devices. Users expect to go to a centralized

hub to download their applications. They also expect the hub to indicate when their software is out of date, and provide those updates when prompted. This follows a centralized control structure, making it easy to push out software changes to the user. Where it falls short is in the distribution of custom made scenarios and environments. Some tablet operating systems make it extremely difficult to transfer custom made content from one tablet to another.

### **3. DVTE**

#### **a. CASE 1:**

The battalion air officer (AO) has gathered a group of perspective JTACs at the simulation center where he is conducting close air support training using the combined arms network (CAN). He chose to execute the training at the simulation center because he can get the support of a dedicated simulation center operator who will run the joint semi-autonomous force (JSAF) server for him. The JSAF server allows DVTE laptops to network together, putting the participants in the same virtual environment.

The AO knows that one of the obstacles to non-aviators successfully completing the course is having an appreciation for the aircraft's perspective, especially when trying to talk the aircraft onto a target. The AO creates a scenario to help the Marines get an understanding of how the same set of roads and buildings looks drastically different depending on the position of the observer. The scenario contains two perspectives; one where the trainee is observing from the ground, and another where a different trainee is observing the battlefield from an overhead unmanned aerial vehicle (UAV) feed. Both trainees are attempting to talk an aircraft onto a target. During the course of the training, no virtual rounds were fired, but a great deal of learning occurred.

#### **b. CASE 2:**

A JTAC assigned directly to a company has been running squad size classes on CFF. The lecture part of the training is over and the JTAC wants

the Marines to get practice in CFF mission planning and execution. He has set up a classroom in Battalion spaces with a squads worth of DVTE laptops. The Marines are running a scenario set in Twentynine Palms. They could be executing the mission planning on the laptops; but in this case the JTAC wants them to do it on real maps, using mapping pens and protractors, as they would do it if called on to conduct the mission in combat. As he is the only instructor, the JTAC created a simple scenario. He spends the training time answering questions and reviewing the Marines mission planning paperwork.

#### **4. Characteristics of the DVTE and Laptops**

As can be seen in the above two examples the CAN allows multiple people to be trained in a classroom setting. The ratio of instructors to students depends on proficiency and the complexity of the scenario. The CAN also has some unique features that the other systems do not; a user can fly an aircraft in the VE or as in Case 1, observe the battlefield through a UAV feed.

One of the drawbacks to the CAN and DVTE is the dissemination of software changes. Not only do the owning units need to get the changes, they then have to install them; a non-trivial task given that 32 laptops are in a DVTE suite. In July 2013, when project manager (PJM) DVTE, John M. Gralin, was asked about software updates to the DVTE, he said:

The software is incrementally developed with efforts occurring each year up to the planned FOC of Sep 2017. Some of these are developmental efforts funded with RDT&E funding and other efforts are considered software maintenance (a.k.a. Post Deployment Software Support [PDSS]) funded with O&M funding. Software upgrades are provided once per year to the fleet primarily through the MEF Battle Simulation Centers. These software updates are provided via the DVTE Software Delivery System (SDS), which is contained on an external hard drive. Once the SDS is plugged into the "Suite", the software will push across the whole suite in approximately 8 hours. Updates to the CAN are included on the SDS and the CAN is currently up to v1.8. Not all versions (v1.0 through 1.8) of the CAN were released to the fleet as some were superseded by later versions prior to the annual update. (J. Gralin, email to author, July 29, 2013)

There are other barriers to the use of the DVTE, especially in battalion spaces. It is time consuming to set up and network the laptops, they take up a decent amount of space, and they are vulnerable to theft.

## **5. Physical Interaction with the DVTE / CAN**

There are some general assumptions about how the DVTE laptops are operated. Though it is possible to set up the laptops in an austere environment, they are typically used in a sanitized classroom with a desk and good lighting; the user has the space to take notes and execute mission planning right at their workstation. The software provides a robust set of mission planning tools. However, as digitized mission planning bears very little resemblance to how it is done in the real world, and as the system provides no direct user feedback based on the accuracy of the mission planning, these tools are rarely used.

### ***a. Input***

The DVTE uses a mouse and a keyboard for user input and most users have a great deal of experience with the two. Unfortunately they do a poor job of capturing the activities one would have to perform when executing the mission. A user sits in a chair staring at the screen, only moving their hands. Cognitively, the trainee might be conducting the correct activities but they are not getting the muscle memory from conducting the psychomotor task of physically moving in order to gain a new perspective.

## **6. SAVT / MSAT**

### ***a. CASE 1***

At the tactical air control party (TACP) course a graded event is underway. Three students, who completed their mission planning the night before, are playing the roles in a Fire Support Team (FiST), one is controlling the aircraft, another is laser designating the target with the portable lightweight designator rangefinder (PLDR) and a third is suppressing the enemy's surface to air threat via indirect fire. A dedicated simulation operator is both running the

SAVT and playing the role of the aircraft. A TACP instructor is taking notes and evaluating the students' performances. The three students cycle through the positions, executing slightly different missions each time.

**b. CASE 2**

In July 2013, Jack Gavin, SAVT operator at Marine Corps Base Twentynine Palms, provided the following case study.

In the SAVT at Twentynine Palms, as part of Infantry Training Exercise (ITX Program), Battalion Fire Support Teams (FiST) under the tutelage of the Tactical Training Exercise Control Group (TTECG) conduct rehearsal exercises prior to executing live fire training aboard MCAGCC. The complete battalion Fire Support apparatus is exercised and coached with regard to safety and efficiency. In attendance are; the unit company FiSTs, The Battalion Fire Support Control Center (FSCC), pilots role playing simulated tactical aircraft from the supporting Aircraft Squadrons, and Coyotes from the TTECG. The simulator itself is operated by a single operator, who is a former naval aviator, or in the case of other SAVT sites, a qualified JTAC. At Twentynine Palms, it is a former AH-1W pilot with 3800 flight hours. In the absence of Role Players from supporting squadrons, the operator will assume the role of the tactical aircraft.

All tools available to the FiST team are integrated into the simulation system, to include; PLDR, IZLID, StrikeLink, and Vector 21b linked to a computer simulated DAGR. The training enables the Battalion Fire Support apparatus to integrate supporting and organic assets to include Aviation, Artillery, Mortars and Naval Surface Fires. As they are conducting training as they might do in combat, the mission planning is ad hoc, they develop target locations, check in aircraft, and execute commander's guidance as to priority of fires. The objective of the evaluation is not on the Marines ability to draw laser baskets and plot coordinates on a map but to control and deconflict multiple assets at once. The location of the simulation exercise closely matches the actual locations they will use during the live fire portion of their training. (J. Gavin, email to author, July 27, 2013).

**7. Characteristics of the SAVT**

The SAVT is the state of the art USMC close air support (CAS) / CFF trainer. It puts the participants on the observation post (OP), with a fully

integrated real-world equipment suite. There are only nine of SAVTs in the DoD. They require a highly trained operator, one who is not only technically proficient with running the simulator but also tactically proficient with the mission sets.

The SAVT is scheduled in the range facility management support system (RFMSS) at least 96 hours prior to the training event. The 96 hour scheduling requirement inhibits spontaneity; units that have a sudden opening in their schedule cannot take advantage of it.

SAVT's instrumented copies of the equipment used by a FiST leads to excellent transfer of training. If the FiST equipment suite changes then the simulator needs to be changed to properly reflect the new equipment. In July 2013, According to Tony "Phu" DiBenedetto, MSAT operator at EWTGPAC:

The most recent tech refresh was 2010 when the GLTD was exchanged for a PLDR, and Strikelink and Video Scout capabilities added. Software upgrades were received with the tech refresh as well. Ideally the next tech refresh will be around the 2015 time frame, which may include additional capability such as the JTAC handheld LTD and a thermal site. (A. DiBenedetto, email to author, July 30, 2013)

### **C. SUMMARIZATION OF THE SIMULATORS**

Table 5 is a summarization of the data relating to the three simulators.



	MSAT/SAVT	DVTE	SAT-M
Location	Only Nine in the DoD	Battalion spaces / Simulation center	Anywhere
Personnel Requirements	Dedicated operator with extensive tactical experience, either a former naval aviator or JTAC	If the laptops are networked together there is usually need for technical support, typically provided by the battle sim centers	User
Networkability	Once, in 2012, as a proof of concept	Yes	Yes
Feedback / Tutoring	Provided by operator	Limited	Yes, but it is recommended that a trained instructor provide occasional feedback
Mission planning	Included equipment has mission planning capabilities	Usually done out of the system	Best done in the system, can be done outside of the system
Input	Instrumented copies of actual equipment used by FiST	Mouse and keyboard	Touchscreen, gyroscope, accelerometer, compass
System updates	When equipment updates during tech refresh	Done yearly and pushed through the battle sim centers	From “the cloud”, and conducted when a change is deemed necessary
Custom scenarios	Yes	Yes	Yes, but hard to share
Availability	Scheduled at least 96 hours in advance	156 Full suites distributed across active duty Marine units	If the user has an Joint Knowledge Online account they can download it. Available to all active duty and reservists
Mobility	No	Yes, but difficult	Yes, no challenges

Table 5. Summary of current simulation tools described in use case scenarios (After A. DiBenedetto, email to author, July 30, 2013; J. Gavin, email to author, July 27, 2013; J. Gralin, email to author, July 29, 2013)

#### D. SUMMARY OF CAPABILITIES

Conceptually, SAT-M will perform much of the same functionality as FOPCSim 2. It will require a robust mission planning capability, embrace the inputs available on a tablet, and provide as much feedback as can be usefully incorporated without inhibiting the training processes. Ideally it will allow an untrained Marine to learn how to execute CFF on their own while not developing improper habit patterns. Table 6 outlines key software capabilities.

Supporting Features	Benefit
Self-location	USMC performance standard, improves user competence
Target-location	USMC performance standard, improves user competence
CFF Procedure	USMC performance standard, improves user competence
Utilization of all T/O Equipment	USMC performance standard, improves user competence

Table 6. SAT-M capabilities

#### E. FUNCTIONAL REQUIREMENTS

The following requirements were developed under the assumption that SAT-M will provide only basic CFF training. In some cases they are carried over verbatim and in others they are an extension and modification of the exhaustive lists generated by both Brannon and Villandre for FOPCSim 1 and McDonough and Strom for FOPCSim 2. Both FOPCSim 1 and FOPCSim2 developed VE CFF trainers. SAT-M is currently in a proof of concept stage, with only enough functionality embedded to allow for execution of the experiment found in Chapter VI.

1. SAT-M shall provide the capability to monitor, score, and evaluate trainee's performance using EWTGPAC standards as a template.
2. SAT-M shall allow the initialization and activation of the simulator into individual training scenarios as well as higher level training scenarios using high level architecture (HLA) connectivity.
3. SAT-M shall provide emulated (i.e., computer generated) forces capable of reacting to indirect fire.

4. The SAT-M simulation shall replicate both enemy and friendly forces including tanks, trucks, personnel carriers, command and control vehicles, reconnaissance vehicles, forward area air defense weapons, dismounted infantry with their associated weapons, mortars, artillery and rockets.
5. SAT-M shall permit users to design new scenarios and revise existing scenarios.
6. SAT-M shall provide the capability to generate new scenarios for the ultimate purpose of mission rehearsal.
7. SAT-M shall provide the capability to place targets and friendly units at specified coordinates on the simulated terrain. Input screen allows user to enter number, type, location of targets, whether they are moving or not, whether they are displayed sequentially or all at once.
8. SAT-M's simulated terrain and environment shall be provided with the following:
  - a. SAT-M shall use the same terrain database as used in the DVTE CAN (threshold). The SAT-M shall allow the user to download imagery and topological information from commonly used internet mapping sites, for example Google Earth. SAT-M will then incorporate the mapping data into a scenario so the user can train with it (objective).
  - b. The following image quality requirements shall apply as a total contribution to the complete integrated visual system (terrain database, image generation system and visual system). Provide the full spectrum of day and night visibility to include sunlight and moonlight effects on terrain. Visual resolution of the simulated terrain shall ensure a true perspective is maintained when distance to an object increases or decreases. The visual system shall be capable of displaying personnel, vehicles, and weapon effects. Objects shall appear in proper size with distinguishing characteristics for the indicated range as viewed through the replicated sighting devices. Terrain feature clarity shall be sufficient to provide appropriate depth perception and distant vision.
9. The SAT-M system shall train and evaluate joint forward observers. The SAT-M will also provide the capability to exercise combined arms to train fire support teams (objective using HLA).
10. The SAT-M will be used to train tasks/events listed in NAVMC 3500.7, Artillery Training and Readiness Manual dated 15 March

2007, NAVMC 3500.42A, Tactical Air Control Party Training and Readiness Manual dated 8 October 2008.

11. The SAT-M shall replicate laser range finder / designator equipment (e.g., GLTD, PLDR) to include target observation, fixed and moving target tracking skills.
12. The SAT-M shall simulate shell bursts to include sound effects of the required projectiles, anywhere in the target area with an observer-target distance of six kilometers (threshold) or 12 kilometers (objective).
13. The SAT-M shall simulate subsequent bursts, specified adjustment correction data given by the forward observer, until a fire for effect or target kill is achieved. Adjustments shall accommodate single gun, single round missions through multiple guns / multiple rounds / multiple (projectile type / fuse type) missions with a threshold of up to six guns.
14. The SAT-M shall measure and record the call for fire, the distance between the target and the impact point of the round(s).
15. Forward observer calls for fire and the adjustment of fires shall be entered as keyboard and dropdown menu inputs to replicate voice procedures (threshold). SAT-M will also all CFF and adjustment to be executed via voice recognition (objective).
16. The SAT-M shall incorporate center gun and adjustment for final protective fire missions.
17. The SAT-M shall simulate smoke screens drifting in a manner appropriate for a 0-20 mph wind and for variable winds to cover all directions (360 degrees).
18. The SAT-M shall simulate illumination and coordinated illumination missions drifting in a manner appropriate for steady and variable winds up to 20 mph.
19. The SAT-M shall determine when rounds or moving targets shall be sensed as unobserved or lost due to the effect of terrain elevation features or obscured visibility.
20. The SAT-M shall provide height of burst (HOB) variations and the ability to adjust HOB for smoke, illumination, and area adjust fire missions and high explosive/mechanical time (HE/MT). Variable HOB to include simulation of air burst without ground effect, air burst with ground effect and mixed bursts of both air and ground effects to include any direction and speed.
21. The SAT-M shall provide simulated air, graze, and mixed bursts accurate to scale and size with respect to the observer-target range.

22. The SAT-M shall delay the distribution of rounds by 10 seconds between subsequent volleys for multiple round missions.
23. The SAT-M shall simulate time of flight of both low and high angle fire missions. The user may select a compressed time of flight option upon scenario selection.
24. The SAT-M will include full function simulation of the following equipment with the latest technology: binoculars, compass with mils and degrees, PLDR, IZLID, thermals, DAGR, Vector 21b and PRC-117. As new equipment hits the fleet it will become available to train with in SAT-M.
25. The field of view shall be 45 degrees. The user will have the ability to rotate their field of view laterally to achieve 360 degrees of visibility. The user will also be able to rotate their field of view 90 degrees up and down to achieve 180 degrees vertical field of view.
26. The SAT-M shall replicate massing of fires at the battery level.
27. The SAT-M shall provide immediate after action review for a given training session (threshold) and archive training data for all students as historical data to focus future training (objective).
28. The SAT-M shall provide mission replay in which all rounds fired can be recalled and repeated.
29. The SAT-M shall provide an instructor tutorial guide/demonstration program.
30. The SAT-M shall provide an instructor mode where one tablet can be set as the instructor, and used to view and manipulate what is happening in the student's tablets.
  - a. The instructor shall be able to damage units.
  - b. The instructor shall be able to regenerate damaged units.
  - c. The instructor shall be able to set unit behavior and assign movement paths to units (i.e. enemy unit is hit by indirect fire, and responds by running, seeking cover, or returning fire).
  - d. The instructor shall be able to add or remove equipment from the student's kit.
  - e. The instructor shall be able to add, remove, and move indirect fire assets.
  - f. The instructor shall be able to add or remove enemy, neutral, and friendly units.
  - g. The instructor shall be able to control the day night cycle, weather and environmental effects.

- h. The instructor shall be able to observe the student's current and past missions, as well as pertinent data such as round accuracy, transmission errors, and recommendations.
- 31. The SAT-M shall compute "did-hit" grid location and HOB for each weapon and mean point of impact and HOB for each fire mission.
- 32. The SAT-M shall perform all known and future types of fire missions.
- 33. The SAT-M shall provide the functions needed to initialize and control the training exercise. The user will have the ability to reenter incorrect data.
- 34. The SAT-M shall record data with a time-stamp in order to identify significant points during the playback to highlight and illustrate lessons learned.
- 35. The SAT-M shall provide a means to initiate and terminate the training exercise.
- 36. Degraded modes will be selectable by the SAT-M at initialization and during any part of the exercise. Examples include ammunition status, navigation malfunctions, communications problems, no binoculars, etc.
- 37. SAT-M shall provide robust mission planning tools.
  - a. SAT-M shall enable the user to plot positions using a virtual protractor laid over a digitized 1:50,000 or 1:100,000 map.
  - b. SAT-M will provide a palette of operational terms and graphics to mark the map with battlefield control measures, friendly, neutral, unknown and enemy units. The user will be able to select an appropriate color when marking the map.
  - c. SAT-M will enable the user to place notes and comments on and beside the marks placed on the map.
  - d. SAT-M will have "under the finger" magnification to compensate for touchscreen inaccuracy.
  - e. SAT-M will correlate user map markings to the location of the virtual units to check on the accuracy of the markings. The system will then provide feedback to the user based on their accuracy.
  - f. SAT-M will have virtual note paper, enabling the user to write on the paper with a popup keyboard, but also draw on it with a selection of pen widths and colors.

- g. SAT-M will have a virtual clipboard where the user can construct and record their CFF missions, mark round impacts, and target numbers.
- 38. SAT-M will provide mission feedback.
  - a. SAT-M will provide real-time prompting, dependent on user set tutoring level, to assist users who are having trouble with mission execution.
  - b. SAT-M will give end of mission feedback based of analysis of expert behavior, and what they would have done in a similar situation.

## **F. NONFUNCTIONAL REQUIREMENTS**

- 1. Usability
  - a. The SAT-M shall train and evaluate joint forward observers.
  - b. The SAT-M shall provide the capability to exercise combined arms to train fire support teams using HLA connectivity.
  - c. Employment tactics. SAT-M shall be operational in any environment that a tablet computer can operate; to include garrison and field environments, SAT-M classroom environments and aboard amphibious ships. This will make SAT-M available to all locations throughout the world where Marines are stationed.
  - d. Employment prerequisites. SAT-M shall not require special support requirements such as site preparation, storage facilities or changes to other items of equipment at the time of initial operational capability (IOC).
  - e. Distribution. SAT-M shall be distributed according to tablet operating system's paradigm. For iOS it will be the App Store, for Android it will be Google Play.
  - f. SAT-M will be downloaded through the Joint Knowledge Online gateway. This is to include the baseline program and additional scenarios and environments.
  - g. Control. SAT-M shall be controlled via the Army Knowledge Online App Store and Google Play gateway.
- 2. Reliability
  - a. SAT-M shall be reliable, available and maintainable.
- 3. Performance
  - a. SAT-M shall be able to operate in a stand-alone mode.

- b. SAT-M shall replicate operational equipment platforms when practical to provide training simulation.
  - c. In accordance with DoD Directive 5000.59 all systems currently under development shall be compliant with HLA.
  - d. SAT-M shall realistically replicate all subsystem sound effects, as well as inter-subsystem communication.
  - e. Subsystem sound effects shall be in proportion to that of the actual weapon operations.
  - f. SAT-M shall simulate the required sensors and controls for each subsystem platform to support required training tasks and tactical exercises.
  - g. The training system's sensors and controls shall represent the physical appearance and replicate the performance of each platform's sensors and controls.
4. Supportability
- a. SAT-M shall be designed for ease of preventive maintenance, repair maintenance, and servicing.
  - b. SAT-M will not require new Marine Corps resources or personnel.
  - c. SAT-M will run on Android and iOS tablets.

## **G. PRODUCT FEATURES**

- 1. The final product shall include interactive 3D graphics with simulated representation of actual terrain. Digitized 1:50,000 and 1:100,000 maps, with a robust mission planning capability. Standard JFO equipment virtualized and usable. User configurable system feedback. An instructor mode to monitor students and adjust the scenario on the fly.
- 2. Inputs
  - a. SAT-M will use device gyroscopes and accelerometer to enable to user to adjust their view in the VE by physically moving the tablet, as if it were a window into the VE.
  - b. SAT-M will enable users to adjust the view in the VE by using the touch screen to pan and swipe the view.
  - c. SAT-M will provide a virtual keyboard that can be stowed when not in use, for entry of text as needed during mission execution.
- 3. Voice input for user action (future)



4. Graphical user interface (GUI) input for user action

#### **H. CONFIGURATION MODULE**

1. Specify types, sizes, and location of targets
2. Stationary and moving targets (future)
3. Choose different terrain sets
4. Choose different observation post locations
5. Choose lensatic or M2 compass (degrees or mils)
6. Allow entry to configuration module during run time

#### **I. VIEW MANAGER MODULE**

1. Binocular view
2. M2 or lensatic compass view
3. Target designator view
4. Thermal view
5. Naked eye view
6. Night vision device (NVD) view

#### **J. USER ACTIONS FIRE MISSION PROCEDURE**

1. Choose type of fire mission
  - a. Adjust fire
  - b. Fire for effect
  - c. Immediate suppression
  - d. Immediate smoke
2. Choose target location method
  - a. Grid
  - b. Polar
  - c. Shift from known point
  - d. Laser polar
3. Input target description (Drop down list to pick from)
4. Choose method of engagement
  - a. High explosive (HE) / Quick
  - b. HE / Time

- c. HE / Variable time
- d. White phosphorus (WP)
- e. WP M825
- f. Improved conventional munitions (ICM)
- g. Illumination
- 5. Enter subsequent corrections
  - a. Left
  - b. Right
  - c. Add
  - d. Drop
  - e. Up
  - f. Down
- 6. Enter observer-target (OT) direction
- 7. End the current mission
- 8. Enter refinements
- 9. Establish known points
- 10. Utilize standard operating procedures (SOP) for immediate missions
- 11. Allow for sequential viewing of targets

## **K. AFTER ACTION REVIEW**

- 1. Immediate playback of last mission
  - a. Playback controls: FF, pause, and rewind control bar
  - b. Show grid location and error for target and each impact
  - c. Provide recommendations for order of mission execution if user deviated from subject matter expert (SME) order.
  - d. Advise user when they skipped a step, did not appropriately calculate a value, did not double check a plot or calculated value, or failed to observe round impacts.
- 2. Save results for later review or print out based on user's name.
  - a. Compile results for user.

## **V. SYSTEM DEVELOPMENT**

### **A. BACKGROUND**

Examining SAT-M through the lens of the model-view-controller (MVC) design pattern was the first step in developing our application. We used the design pattern to explore the differences and similarities between desktop / laptop and tablet VE trainers. This helped us determine where to focus our limited resources and therefore maximize development efforts. Throughout the process we leveraged validated CFF VEs, primarily ObserverSim.

#### **1. Model-View-Controller**

MVC assigns the software objects that make up a program “one of three roles: model, view, or controller” (Apple Inc., 2013). Conceptually each software object is an isolated entity that does not require knowledge of how other objects work. The objects interact by providing information when requested and asking for information when needed.

We used the MVC pattern to examine our development efforts based on the roles that need to be fulfilled by each object, rather than in a strict object oriented programming sense. We abstracted the concept and applied it to the entire program, splitting it into the roles of model, view or controller.

The model portion of the software “encapsulate[s] the data specific to an application and define[s] the logic and computation that manipulate and process that data” (Apple Inc., 2013). The view portion of the software knows how to display, and might allow users to edit, the data from the application’s model (Apple Inc., 2013). The controller portion of the software acts as an intermediary between the view portion and the model portions of the program. It is a conduit through which the view learns about changes in the model and vice versa (Apple Inc., 2013).

SAT-M was initially conceived to run on both Android and iOS devices, thereby including both tablets and smartphones. Utilizing the MVC design pattern allows for code reuse, as only the portion of the software that interacts directly with the system would need to be changed.

What follows is a discussion of the model and view aspects of the MVC pattern as it pertained to our development effort. As we were unable to obtain the source code or design documents for ObserverSim, there is little we could infer about its implementation of the controller. We are therefore unable to leverage the ObserverSim's controller in our development efforts.

Incidentally, MVC is the design pattern driving the Cocoa and Cocoa Touch frameworks used by Apple in their iOS software development kit.

#### ***a. Model***

The model portion of a VE CFF program is comprised of the data necessary for it to run, as well as the associated logic. This includes textures, models and terrain data. It also includes the functionality of that data. For example, the virtualized vector 21b is composed of both screen display information and a program that informs vector 21b response behavior when it is used.

When developing SAT-M we knew that there would be almost no difference between ObserverSim and SAT-M's model; the data for Twentynine Palms terrain and a virtualized vector 21b are the same regardless if it is displayed on a desktop or a tablet system.

#### ***b. View***

The view portion of a VE CFF program consists of how the information is presented to, and how the program accepts inputs from, the user. Due to both the differences in input modalities and screen size between laptop / desktop and tablet computers SAT-M and ObserverSim diverge the most in this area, making this our primary focus of development effort.

Our effort started by mapping the mouse and keyboard inputs of ObserverSim to one of the input modalities of the tablets. At our disposal were the multi-touch enabled touchscreen, accelerometers, and gyroscopes. From conception we knew that we wanted to have the user's perspective controlled by the accelerometers and gyroscopes. Adding a single finger swiping interface to control the view was discussed but never implemented. At one point we had the program automatically switch to mission planning mode when the tablet was turned horizontally. The idea was conceptually interesting, but impractical as it caused issues when users put the tablet down to take notes and the display unexpectedly changed.

Once it was established that accelerometers and gyroscopes would control perspective the remaining inputs were either mapped to the multi-touch enabled touchscreen or eliminated. Translating the mouse input for ObserverSim to the tablet was relatively easy, instead of point and clicking, the user touches the desired button to push. There are some challenges with this methodology as a finger occludes the screen, is less precise, and larger than a mouse pointer. Whenever possible, to avoid difficulty when a user has only one hand available, we made the buttons large and near the edge of the screen, thereby allowing the user to hold the tablet and press the buttons with their thumb. Figure 6 is a screen shot of SAT-M in the vector 21b view.

Buttons for selecting devices are arrayed on the left side of the screen, permitting easy use when the tablet is held in the left hand. Future developments include giving the user the option of choosing which side to place the button bar.



Figure 6. Screen capture of SAT-M's vector 21b view

In only one instance does ObserverSim use the right mouse button, and this for gathering range information with the Vector 21bs. In ObserverSim, if the both the left and right mouse button are pressed while in Vector 21b mode heading and distance to the object under the “pointing circle” is displayed. In Figure 6 the “pointing circle” is just below the technical vehicle. This rare use of the right mouse button caused problems for some of the research participants in the experiment, see Chapter VI. Some of the participants who had difficulties had to be told to use the right button, as they would try and left click on the range button and only get heading. The multi-touch enabled touchscreen allows SAT-M to get around this confusion. The user can press both buttons at the same time, or one at a time, as they see fit. In Figure 6, the two aforementioned buttons are to the left and right of the vector 21b view, the direction button is as a plus sign in a circle and the range button is as a white arrow.

Mapping the keyboard from ObserverSim to SAT-M was more difficult than mapping the mouse. In the interest of limited development time, we chose to use drop down menus, rather than include a fully functional keyboard. This resulted in the elimination of user controlled walking motion. In ObserverSim pressing W, A, S or D moves the user forward, left, right or backwards respectively. Just as in FOPCSim, we chose to have the user stationary; with one less input to map we were able to keep SAT-M controls simple.

ObserverSim not only uses the keyboard to move around the VE world, but also uses it for entering mission data. In SAT-M we chose to either auto populate the mission data, or use dropdown menus. Auto populating the data required additional logic to ensure that the user had collected the data that was to be auto populated. We ensured that the drop down menus had the pertinent options given the missions the user could execute. Using drop down menus limits the flexibility of the software but allowed us to avoid the implementation of a virtual keyboard and the underlying logic for parsing the inputs. In the experiment, see Chapter VII, a few of the research participants had an issue with the way we mapped ObserverSim's (Figure 7) keyboard inputs to SAT-M's touchscreen.

The Dell Precision M6300 laptops that come with the DVTE suit have 17" displays, this equate to three times the area of the Asus Transformer Pad Infinity's 10.1" display. To compensate for the small screen size the mapping of icons and viewable area was altered. Figures 7 and 8 are screen captures from ObserverSim and SAT-M respectively, both taken in the naked eye view. Differences between the two include the placement of the JFO tool icons, the relative size of the icons, and the decision to have SAT-M's icon tool bar occlude the background.

In SAT-M the JFO tool icons were placed in an occluding bar and on the side of the screen to facilitate the touchscreen interface. As mentioned earlier, having the icons on the side of the screen makes the icons easier to select when the user is holding the tablet. Having the toolbar occlude the

background creates a region of the screen where the user's only interaction is tool selection. This prevents the user from accidentally sending another command if they missed the desired tool. For example, if the interface allowed for finger swiping to change perspective the system might infer a missed tool touch as a finger swipe, changing the viewer's perspective and potentially disorienting them.



Figure 7. Screen capture of ObserverSim's naked eye view

SAT-M's icons are larger (Figure 8), relative to the screen, than ObserverSim's icons (Figure 7). If they had maintained the same size ratio they would be difficult to select, inhibiting ease of use. A nice side effect of the larger icons is that they do not need to have extra text describing what the icon is, as can be seen in ObserverSim's screen capture (Figure 7).



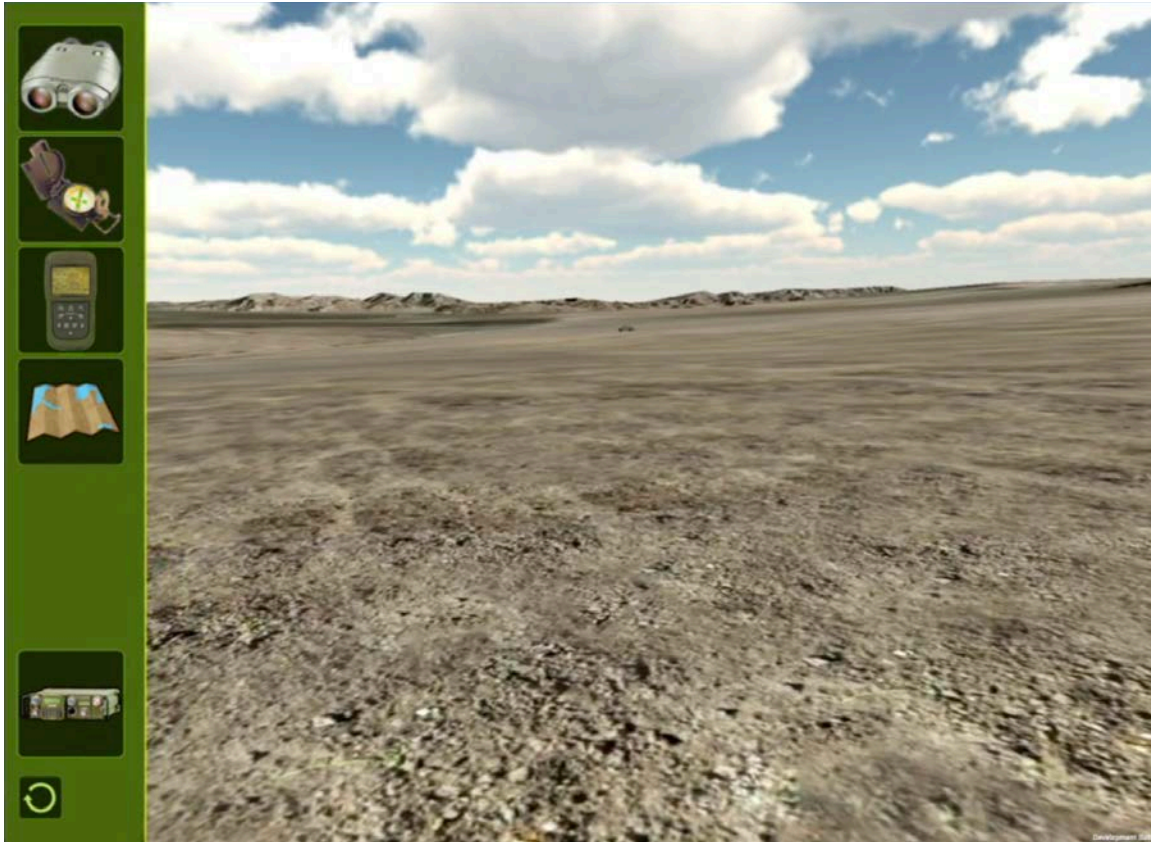


Figure 8. Screen capture of SAT-M's naked eye view

## **B. INTERFACE DESIGN STUDY**

An interface design study was performed to facilitate user interface development. The intent was to create an effective user interface for the SAT-M, and to include scenario election, mission execution and mission planning. Mock up screens were created in HTML. These allowed a user to flow through a mission, starting with the creation of a user profile. Though much of this work did not end up in the current build of SAT-M, it did facilitate SAT-M development by providing the development team with conceptual images and story boards. Appendix A includes the complete interface design study.

### **C. OPERATING SYSTEM AND HARDWARE SELECTION**

At the time SAT-M development began, the two dominant mobile operating systems were iOS and Android. To ensure our program would reach the widest audience, we decided to develop software for both.

SAT-M is not dependent on cellular network access, which simplified our platform choices. A 3rd generation iPad with 16 GBs of internal flash storage, the least expensive and most up to date model available at the time, represented the iOS platform. A comparable Android device, the Asus Transformer Pad Infinity, model TF700T, was chosen for its similar performance, screen size (10.1” versus 9.7” on the iPad) and inputs, which include gyroscopes, accelerometers, and a multi-touch enabled touchscreen.

### **D. BACKEND LIBRARY SELECTION**

Due to our requirement that SAT-M run on both Android and iOS, the unity 3D game engine was chosen as the backend library. Unity 3D allows the developer to build the software application once and “compile” it for different target platforms, making it relatively easy to port from one platform to another. An additional advantage of Unity3D is that a developer license is relatively inexpensive and once “compiled” the runtime application can be distributed without additional license costs. License cost is per-developer; the generated application may be used without additional license fees (Unity Technologies, 2013).

### **E. SOFTWARE PRODUCTION**

The software was not written by the authors; we used the visual simulation and game-based technology team located at NPS. As the team supports the MOVES Institute the authors had ample access to the developers, allowing for quick turn around with any issues or need for clarification.

The basic application premise was discussed with the software developers early in the project. Using accelerometers and gyroscopes to control the

perspective (vis á vis W2W) in a CFF VE had not been done before, numerous tech-demonstrations were created to validate the idea. Once both the Asus and the iPad satisfactorily demonstrated W2W, the user interface was discussed and planned.

The HTML interface designed and tested previously was demonstrated to the development team, who then implemented the button graphics and logic. The devices to be simulated in the software were discussed with the team as well as the general CFF process. This gave the team enough information to be able to implement a simplistic simulation of each device required by the software.

The simulated 3D terrain was built using real-world data, with subsequent modifications to increase the graphical fidelity. The 3D models were taken from an in-house library and customized to support the application. Audio assets came from a commercially-licensed audio library and adjusted to provide adequate audio feedback to the user.

Regular meetings with the development team allowed for frequent feedback. This process ensured the limited resources for the development of the software was efficiently used.

## **F. LIMITATIONS**

As mentioned earlier, during the development of SAT-M there was an attempt to have it mirror ObserverSim as much as possible. That effort was restricted by the limited amount of time and development resources available for the project. The version of SAT-M used in the experiment, see Chapter VI, had a number of key differences. In some cases the authors specifically wanted SAT-M to be different than ObserverSim.

- SAT-M did not have a virtual keyboard. When the CFF and position report (POSREP) are generated on ObserverSim the user inputs much of the data via the keyboard. To get around this SAT-M either auto populated the information when prompted by the user or used drop down menus.

- ObserverSim had a fully functional DAGR. The buttons on the virtual DAGR functioned as they would on a real DAGR. SAT-M used a static screen shot of the DAGR's present position screen.
- In developing the scenario for the experiment in ObserverSim it was not possible for the authors to precisely select the set of equipment they wanted to have available to the user. As SAT-M was developed from scratch only what was appropriate to the experiment's tasks was presented to the user. Some of the extraneous equipment in ObserverSim was the clipboard, and the NVGs and StrikeLink interconnect in the Vector 21b view. Figure 7 is a screen capture from ObserverSim running the experiment's scenario. The extraneous clipboard icon is just below the compass icon.
- In ObserverSim there was no need for the user to echo back either the message to observer (MTO) or the shot call. Failure to respond to the shot call from the fire direction center (FDC) will not jeopardize the fire mission but failing to respond to the MTO will. It was the authors' opinion that not including the required MTO response resulted in negative training and we added this call to SAT-M.

## **G. CONCLUSION**

The process was completed when a tablet version of CFF VE software was created that would allow the authors to satisfactorily compare it to similar software on a desktop / laptop PC. Key functionality of the software was comparable, which allowed the experiment to focus on the disparate input modalities.

## **VI. EXPERIMENT**

### **A. BACKGROUND**

McDonough and Strom, in their work on FOPCSim 2, showed that a PC based VE CFF trainer can improve performance. Though their results were constrained by not being able to conduct a graded live fire event, there was enough evidence to show that the software they developed did indeed improve student performance. In essence SAT-M is an updated version of FOPCSim. It brings the simulator to tablet systems while updating it to reflect eight years of technology advancement. The experiment was designed to see how viable the input modalities of the tablet system are when compared to the existing standard set by desktop / laptop systems. The focus was not on whether SAT-M could improve training but if window to the world (W2W) is a viable way to conduct CFF training, and to try to discover why or why not.

### **B. HYPOTHESIS**

H0: Users have no preference between using a laptop based VE CFF trainer and using a tablet based VE CFF trainer.

H1: Users will prefer to use one of the devices over the other.

This is the overall hypothesis of the study. However additional data was collected to help elucidate why the participants may or may not prefer one system to the other.

### **C. METHOD**

#### **1. Participants**

A total of 32 active duty personnel participated in the study. They varied in rank from O-1 to O-4, one was female and 31 were male. The participants were drawn from two populations, those trained in CFF and those not trained in CFF. An individual was considered trained if they had been to a school dedicated to combined arms training, i.e. Field Artillery School, JFO course, or TACP course,

or had been designated by their commanding officer (CO) to conduct CFF. There were exceptions to the classification. In a number of cases USMC weapons platoon commanders were classified as trained. A weapons platoon commander is the leader of company's FiST, and would have extensive on the job training. In another case, an individual had had extensive CFF experience over a decade ago and none since, was classified as untrained.

## **2. Apparatus and Location**

### ***a. Equipment***

Equipment includes a standard USMC issued Deployed Virtual Environment Training (DVTE) suite, running the ObserverSim software. ObserverSim is a PC CFF simulation developed for the Marine Corps and based on FOPCSim. The tablet PC chosen was the ASUS Transformer Pad Infinity, model TF700T, which ran the SAT-M tablet based simulation. Additional equipment included stopwatches, clipboards, writing materials, video recording equipment, and two laboratory spaces.

### ***b. Location***

The experiment was conducted aboard Naval Postgraduate School, in Watkins Hall MOVES Laboratory and Glasgow Hall Human Systems Integration Laboratory.

## **3. Scenario**

Despite the difference between graphical representation and fidelity the authors attempted to have the scenarios on the two devices as similar as possible. The overall scenario had the user in Twentynine Palms with two targets, an open back pick-up that represented a technical, and a T-72 Russian main battle tank. The targets were placed such that the user would not be able to see both at once. They were outside of danger close and within unaided visual range. The scenario was set in the day. The indirect fire unit was "kilo" battery,

consisting of 155 mm howitzers. Additional differences between SAT-M and ObserverSim are discussed in Chapter V, section F.

#### **4. Procedures**

##### **a. Tasks**

Tasks conducted were derived from the Brannon and Villandre CTA produced in 2002 (the full text of the CTA is on pages 17 through 42 of Brannon and Villandre). They include the use of GPS for self-location, use of a compass to determine bearing to a target, use of a Vector 21b common laser range finder (CLRF) to determine bearing and distance to a target, and the use of the software to generate, send, and then execute a CFF mission. These are common tasks that a JFO would complete in order to build and execute a fire mission.

The experiment went as follows:

- Obtain consent
- Complete proficiency questionnaire
- Execute Protocol “A”, using either the laptop or tablet, device order was semi-randomly selected. Protocol “A” is:
  - Task #1—Determine self-location
  - Task #2—Determine bearing to target A with compass
  - Task #3—Determine bearing and distance to target B with CLRF
  - Task #4—Describe icon used to transmit CFF
  - Task #5—Generate and execute CFF brief
- Complete Likert scale and open ended questionnaire.

- Execute Protocol “B”, which is identical to Protocol “A” except the participant switches device, and the Likert scale and open ended questionnaire has four additional questions that directly ask the participant about device preference, as well as a final open ended question.
- Complete a demographic questionnaire.

Examples of the protocols and questionnaires can be found in appendix B, experimental design details.

***b. Conditions***

The experiment was a two by two cross-over design as shown in Table 7. This allowed the authors to control for the possibility a participant might prefer one of the devices over the other due to the order they were presented.

	Experience	
Device	Trained	Untrained
Tablet	Trained observer using tablet	Untrained Observer using tablet
Desktop PC	Trained Observer using PC	Untrained Observer using PC

Table 7. Two by two cross-over design



## **VII. RESULTS**

### **A. GENERAL**

The overarching goal of the experiment was to determine how viable the input modalities of the tablet system are when compared to the existing standard set by desktop / laptop systems. However, as the two platforms were running different software it is possible that platform preference was due to the software and not the hardware. As mentioned in Chapter V, to reduce participant bias there was a concerted effort to have SAT-M's interface and functionality mirror that of ObserverSim's.

### **B. LIKERT SCALE QUESTIONS**

Two sets of 10 identical Likert scale questions were asked during the course of the experiment. Of the 10 questions, six had to do with the interface, two pertained to the systems effectiveness as a CFF trainer, and the last two related the system's ability to mimic the real world physical activity and motion required to execute the tasks. Each question set pertained to one of the systems, either laptop or tablet. The Likert scale questions were analyzed using a Wilcoxon Signed-Rank test. A two-tailed  $\alpha$  of 0.05 was used. Table 8 contains the results of this analysis. Five out of the 10 questions had a statistically significant difference between the participant's answers at the 0.05 threshold. In the five cases when there was statistical significance the participants preferred the tablet system to laptop system.

Two additional Wilcoxon Signed-Rank tests were evaluated. The first was on a summation of all 10 Likert questions. The test was run to see if there was an overall device preference. In the second test, as some of the Likert questions were very similar to each other, the average scores of these questions were used. This was done to eliminate the possibility that the same sort of question was overly influencing the results.

## 1. Analysis of Likert Questions

### a. ***Question 1: Training with this Device on a Regular Basis Will Improve My Ability to Conduct CFF in the Field***

With a p-value less than 0.002 the participants' responses provided a greater indication that the tablet system will improve their ability to conduct CFF in the field when compared to laptop system.

### b. ***Question 2: It Was Difficult Navigating through the Device to Find the Appropriate Information While Completing the Tasks***

With a two-tailed p-value of 0.0794, there is no indication of system preference.

### c. ***Question 3: The Real-World Physical Actions and Conducting A Task In The Virtual Environment Are the Same***

With a two-tailed p-value of less than 0.001, the participants' responses provided a greater indication that the actions conducted in the physical world and the actions conducted on the tablet systems VE are more similar than the physical world to laptop system comparison.

### d. ***Question 4: The Button Icons Provide Intuitive Inference of What Would Happen When They Are Pressed***

With a two-tailed p-value of 0.44, there is no indication of system preference.

### e. ***Question 5: It is Easy to Move though the Screens without Losing One's Place***

With a two-tailed p-value of 0.22, there is no indication of system preference.

***f. Question 6: Having This Software Available at My Unit Would Improve My Units Ability to Perform Their Mission***

With a two-tailed p-value of 0.051, there is no indication of system preference.

***g. Question 7: It Was Hard to Understand what the Buttons Did***

With a two-tailed p-value of 0.24, there is no indication of system preference.

***h. Question 8: The 3D View Interface Was Intuitive***

With a two-tailed p-value of less than 0.04, the participants' responses provided a greater indication that tablet system's 3D view interface is more intuitive than the laptops system's 3D interface.

***i. Question 9: The Device Accurately Represents the Real World Physical Motion Required to Conduct the Task***

With a two-tailed p-value of less than 0.002, the participants' responses provided a greater indication that tablet system more accurately represents the real world physical motion required to conduct the task than the laptop system.

***j. Question 10: The Overall Interface is Intuitive***

With a two-tailed p-value of less than 0.009, the participants' responses provided a greater indication that tablet system's interface is more intuitive than laptop system's interface.

***k. Summation of All 10 Likert Question Answers***

With a two-tailed p-value of less than 0.002, the participants' responses indicated an overall preference for the tablet system over the laptop system.

## ***I. Summation of Likert Questions, Eliminating Redundancy***

Four sets of two Likert scale questions were similar to each other. For example, Q8: The 3D view interface was intuitive, and Q10: The overall interface is intuitive, are in essence asking the same thing. To prevent this and similar redundant questions from overly influential the results, the average of the redundant questions were used in the calculation. The similar questions are Q2 and Q5, Q3 and Q9, Q4 and Q7, and Q8 and Q10. Questions Q1 and Q6 were unique and their values were added as is. The resulting two-tailed p-value was less than 0.001, when redundancy was eliminated the participants showed an overall preference for the tablet system over the laptop system.

## **2. Summary of Results**

Table 8 is a summary of the results of the tests. The rows correspond to the Likert scale questions or the aggregated results of the Likert scale questions. The columns provide insight into the results of the Signed-Rank test. The second column, "n", is the number of non-zero values after the difference between the paired data was calculated. The third column is the summed signed ranks for the difference of the paired data when the participant preferred the tablet system. The fourth column is the summed signed ranks for the difference of the parried data when the participant preferred the laptop system. The two tailed p-value was the probability of the values in the third and fourth columns appearing if the mean of the answers were equal.

	n	Summed signed ranks		2 tailed p-value
		Tablet System	Laptop System	
Q1	13	91	0	0.0013
Q2	22	180.5	72.5	0.0794
Q3	21	215.5	15.5	0.0005
Q4	18	103.5	67.5	0.4362
Q5	22	164.5	88.5	0.2168
Q6	11	55	11	0.0511
Q7	24	191	109	0.2388
Q8	21	173.5	57.5	0.0392
Q9	23	241	35	0.0015
Q10	23	223.5	52.5	0.0083
All	30	383.5	81.5	0.0019
Eliminate Redundant Questions	29	371	64	0.0009

Table 8. Wilcoxon signed-rank test results for Likert scale questions asked post experiment

### 3. Analysis Tools

The data was analyzed in R using the Wilcox.test function. Histograms were generated to determine symmetry around the median using JMP. Ideally when conducting a Wilcoxon Signed-Rank test, the data will have no zeros, there will be no ties, and the data will be symmetric around the median. In the case of this data there were ties, zeros and in some cases the data was not perfectly symmetric. However, when the test indicated that the results were significant, except for Q8, the p-value were all less than 0.01. Q8 was symmetric around the median and the authors feel comfortable stating that there is significant difference between the medians of the participants' answers as it pertains to this question.

### C. DIRECT QUESTIONS

After completing the second protocol and answering the associated 10 Likert scale questions the participants were asked four direct questions,

numbered 11 through 14. The direct questions had the participant specifically state a preference between the laptop and the tablet systems. The questions allowed the authors to directly ask for a preference, and in the case of questions 12 and 13 to a limited degree control for differences between the two systems. The answers were analyzed using a sign test. Table 9 is a summary of the results and analysis.

## **1. Analysis of Direct Questions**

### **a. Question 11: Which device was more intuitive to use?**

With a p-value of less than 0.004 the participants thought the tablet system was more intuitive to use than the laptop system.

### **b. Question 12: If the software on both devices were about equivalent I would prefer to use?**

With a p-value of less than 0.0006 the participants would prefer to use the tablet system instead of the laptop system if the software on the devices were about equivalent.

### **c. Question 13: If each device had the same feature set I would prefer to use?**

With a p-value of less than 0.0002 the participants would prefer to use the tablet system instead of the laptop system if the devices had about the same features.

### **d. Question 14: This device is more convenient to train with?**

With a p-value of less than 0.021 the participants thought the tablet system was more convenient to train with than the laptop system.

## **2. Summary of Results**

Table 9 is a summary of the results of the tests. The rows correspond to the questions. The second and third columns are the number of participants who

answered tablet or laptop to the question. The right most column, p-value, is the probability of the values in the second and third column if the chance of either being chosen is 50 percent. In Question 11, one of the participants had no preference; hence the sum of the laptop system and tablet system columns is 31 instead of 32.

Question	Tablet System	Laptop System	p-value
11	24	7	0.003327
12	26	6	0.000535
13	27	5	0.000113
14	23	9	0.020062

Table 9. Direct Question Sign Test Results

### 3. Analysis Tools

The data was analyzed in Excel using the cumulative binomial distribution with a probability of 0.50. The number of trials was the number of participants, 32, except for question 11, where one of the participants wrote in the response “same,” then it was 31. The resulting probability was doubled to account for a two tailed p-value.

## D. TRAINING AND ORDER

An evaluation was conducted to investigate if system use order or training had an effect on the data collected. Two-sample *t*-tests were run on the difference values between the Likert scale questions in the two protocols. The tests were run to determine if the mean values of trained and untrained, and the mean values of laptop first and tablet first were different.

### 1. Summary of Results

A summary of the results of the tests is found in Table 10. In nearly all cases the training level of participants and the order the devices were used demonstrates no statistically significant difference. However, a difference was found in regards to Q3, “The real world physical actions and conducting a task in

the virtual environment are the same”. Both training and order have a statistically significant effect on the participants’ answers to Q3. If the participant was untrained or used the laptop first they gave the tablet system a higher score than the laptop system.

	Two Tailed P-Values	
	Training	Order
Q1	0.5320	1.0000
Q2	0.6675	0.6674
Q3	0.0491	0.0469
Q4	0.1763	0.8246
Q5	0.6111	0.1797
Q6	0.0694	0.4800
Q7	0.1559	0.6399
Q8	0.6004	0.2913
Q9	0.2458	0.6457
Q10	0.1560	0.727
Summed	0.2909	0.8768
Redundancy Removed	0.1291	0.8387

Table 10. Two Sample *t*-test for Training and device order

## 2. Further Analysis

A one-way ANOVA test, using JMP, was run on the four item data subset pertaining to Q3. The test returned a probability of 0.0377, showing significance at  $\alpha = 0.05$ . Table 11 has the means and the lower and upper 95% confidence intervals.

	n	Mean of difference between laptop and tablet answers	Lower 95%	Upper 95%
Trained and laptop First	8	-1.375	-2.387	-0.363
Trained and tablet First	8	0.000	-1.012	1.012
Untrained and laptop First	8	-2.125	-3.137	-1.113
Untrained and tablet First	8	-1.375	-2.387	-0.363

Table 11. Results of Oneway ANOVA on Q3



## **E. OPEN ENDED QUESTIONS**

The open-ended questions were phrased to allow participants the opportunity to express what they felt was most pertinent from their experience with the systems. As expected there were a variety of answers. Some related directly to certain features of the software, for example “Compass should have metal filament that lined over radial direction to aid in giving accurate report”. Such statements are interesting in terms of how accurately digitized equipment represents real world equipment, but they do not drive at the authors’ research. Fortunately, many of the remarks not only confirmed the results of the Likert scale and direct questions but also provided some surprising insights.

The most popular subject of comment involved the physical motion required by the tablet system. These ranged from simple statements, such as “Tablet has more realistic feel due to physical activity required as in the real world,” to more thoughtful ones, such as noticing increased opportunities for training. Some of the more nuanced comments related to the differences between using the Vector 21b and compass on the tablet system and using the two virtual devices on the laptop system. It is time consuming to ensure that the “pointing circle,” the laser recital, is over the target when using a physical Vector 21b. This task frequently requires more than one “squirt”, a colloquialism for ranging the target, and multiple confirmation “squirts” to ensure that one has the right distance and heading. In the laptop system the 3D view is controlled with a mouse. When using this input modality the “pointing circle” of the Vector 21b stays exactly where it is placed and perfectly still. This creates a condition where determining the heading and distance becomes unrealistically easy, and there is no need to confirm with a second or third “squirt”.

To a limited degree the aforementioned condition occurs when using a floating dial compass virtual device on the laptop system. When using a physical compass it takes time for the floating dial to come to a rest and requires a steady hand to ensure the reading is accurate. When using the laptop system, the compass always gives a perfect bearing to whatever is lined up with the sighting

wire. To get a good bearing with the tablet system the user needs to steady the system gyroscopes and accelerometers. Although the Vector 21b and compass are not particularly challenging to use, it is harder than the laptop system makes it appear, whereas the tablet system replicates some of the real world motor skills required to conduct the task. A comment from one of the participants summed this notion up nicely “The laptop was easier to manage in terms of pointing and clicking, but the tablet better approximates holding up the vector”.

Analysis of Likert scale questions three and nine show that participants believed the tablet system was more representative of real world physical action and motions required for task execution. A number of statements supported this finding. “I liked the tablet a little more b/c it did a little better mimicking actual use of hands and some of the physical motion of looking around & up/down”. Participants also like the physical motion that the tablet system requires because it helped them maintain their orientation within the 3D world, “It was much easier to locate TGTs and not get disoriented when using the tablet”. Other comments related to the way the physical motion helped maintain participant attention, “Tablet was generally better in that it kept my attention through the requirement of movement”.

The authors expected the participants to make comments similar to the first, but were surprised with how W2W helped participants maintain their orientation in the VE and increased the participant’s attention. This is especially interesting when considering how the tablet system was significantly less refined than the laptop system, with a crude interface and simple and repetitive 3D terrain.

A number of remarks related to the advantages of training with a tablet system over a laptop system. Others commented on the mobility and ease of access for a tablet system, “Very easy to use. Small & portable—convenience factor is huge”. One participant stated on how the mobility of the tablet allows the

trainee to get out of the classroom and practice in more realistic conditions, “You could take it outside put soldiers in full body armor & simulate a CFF w/out the range”.

A significant number of comments discussed how to make both the tablet system and laptop system better. Voice recognition was the number one desired feature for both devices, allowing the VE user to speak the CFF, as they would in the real world, instead of filling out forms. The second most desired feature pertains to the limitation of the SAT-M development effort. Respondents wished the user could manually enter data into the CFF instead of having that data auto populate. Numerous participants were concerned with the possible negative training effects of auto population. One commented, “The laptop was better only because it had less preformatted response information, which forced me to do like I would in real life and remember, write down, or reference tools to complete CFF”.

## **F. DISCUSSION**

Information collected during the experiment can be generally characterized as either a direct or evaluated comparison of the desktop / laptop and tablet systems. The former was collated from direct questions and the latter from the Likert scale results and answers to the open ended questions. Participants’ opinions about the software or their opinions about the specific hardware were not the focus of the authors’ investigation. We concentrated instead on what participants thought about the more generic concept of VE training simulation as designed for tablet devices. That is, the focus was not on SAT-M running on an ASUS Transformer Pad Infinity, or ObserverSim running on a DELL Precision M6300 laptop, but rather in the holistic concept of VE training software running on different devices.

The results of the experiment were used to answer research questions one through four:

1. Is a VE trainer on a tablet possible?
2. Is the “Window to the world” paradigm seen as a valuable addition to VE training?
3. Would military officers trained in CFF see a value in VE tablet CFF training?
4. Would military officers untrained in CFF see a value in VE tablet CFF training?

#### **1. Is a VE trainer on a tablet possible?**

The development effort shows that it is possible to create a tablet VE training simulation. Five of the ten Likert scale questions (Table 8) and all four of the direct questions (Table 9) demonstrate participant preference for the tablet system over the laptop system. This indicates that not only can a tablet VE training simulation be created; but that the participants feel it is a superior platform for CFF VE training when compared to desktop / laptop systems.

Most surprising is that in no way is this a fair comparison. The SAT-M software was in an immature stage of development, with a far rougher VE when compared to ObserverSim, the result of multimillion-dollar procurement.

#### **2. Is the “window to the world” paradigm seen as a valuable addition to VE training?**

Almost all comments to the open ended questions indicated a positive response to the W2W paradigm. W2W on the tablet system makes the simulator more than just a cognitive skill and specific knowledge trainer. As discussed in Chapter III, the system has the potential to train those physical activities necessary to execute a CFF mission.

The developers of the DVTE suit recognized that negative training could occur when the user stares at a stationary monitor. Each DVTE suite includes a head mounted display (HMD). With the HMD the user moves their head to look around in the VE as they would in the real world. This places the user directly into the VE. Unfortunately, this makes it hard to see anything in the real world, including the CFF they carefully wrote down and the keyboard for typing

instructions. Due to these limitations, the HMD is only worn in the final portion of the DVTE mission, when there is little need to double check notes and finger placement. W2W does not have any of these issues; the multi-touch screen is both the user's view of the world and interface.

### **3. Would military officers both trained and untrained in CFF see a value in VE tablet CFF training?**

As there is little response difference between the trained and untrained participants, it appears that they both see potential in tablet VE CFF training. The simplicity of the interface allows for the untrained to quickly grasp how the devices are used, whereas W2W lets the trained work on both cognitive and psychomotor skills.

### **4. Further Discussion**

Cognitive load theory describes three categories: intrinsic load, germane load and extraneous load. Intrinsic load is “the mental work imposed by the complexity of the content in your lessons and is primarily determined by your instructional goals” (Clark, Nguyen, & Sweller, 2006). In CFF intrinsic load is the base line mental tasking that is a result of using the equipment and planning and executing the mission. Germane load is “mental work imposed by instructional activities that benefit the instructional goal” (Clark et al.). In CFF training this is represented by the specifics of the scenario designed to make the CFF either simpler or more complex depending on the learning objective. Extraneous load “imposes mental work that is irrelevant to the learning goal and consequently wastes limited mental resources” (Clark et al.). In simulated CFF training extraneous load is any effort the user spends figuring out how to use the interface, navigate the systems screens and orient themselves in the VE. Observations of the 32 participants executing the same mission on both tablet and laptop systems leads the authors to conclude two important points:

- System preference had nothing to do with software or system fidelity
- System preference was influenced by how the tablet system reduces extraneous cognitive load, allowing the participants to focus their mental efforts on executing the mission and not fighting the interface

## **VIII. CONCLUSION**

### **A. GENERAL OBSERVATIONS**

There were three areas that the authors explored in this research. We looked at the software differences between SAT-M and ObserverSim, the use of multi-touch touchscreens as an input device versus a mouse and key board, and we explored the use of the W2W as a way to train psychomotor skills. In this effort we reused and validated a previously developed CTA, applied a HARs assessment to tablet systems to validate real world to VE action mapping, assessed how the tablet system would be used, developed an experiment, and analyzed the results. By incorporating new technology into the process and leveraging existing work our feeling is “the whole is more than the sum of its parts”. From the outset of this process we expected that the participants would find using the multi-touch enabled touchscreen to be more intuitive, and that they would also find that the W2W allowed them to train psychomotor skills.

### **B. SUCCESS**

The work in this thesis establishes a precedent for early adoption of new technologies and a design process that leverages preexisting methodologies with an emphasis on reuse of prior work. The inherent potential for quality VE training in tablet system is exhibited throughout the process the authors followed. We successfully created a VE trainer on a tablet and it was considered a viable way to train CFF by both experienced and inexperienced research participants. Further, our investigations into the W2W paradigm were reported by the participants as a better way to train than using a traditional mouse and keyboard. Perhaps the most unexpected finding, as well as most rewarding, was the potential for W2W to increase a participants attention and interest in the training and reduce the cognitive “overhead” that results from training in a VE. Key takeaways of this research from the authors’ perspective included:

- The W2W paradigm creates a new area for improving training in VEs (Figure 9)

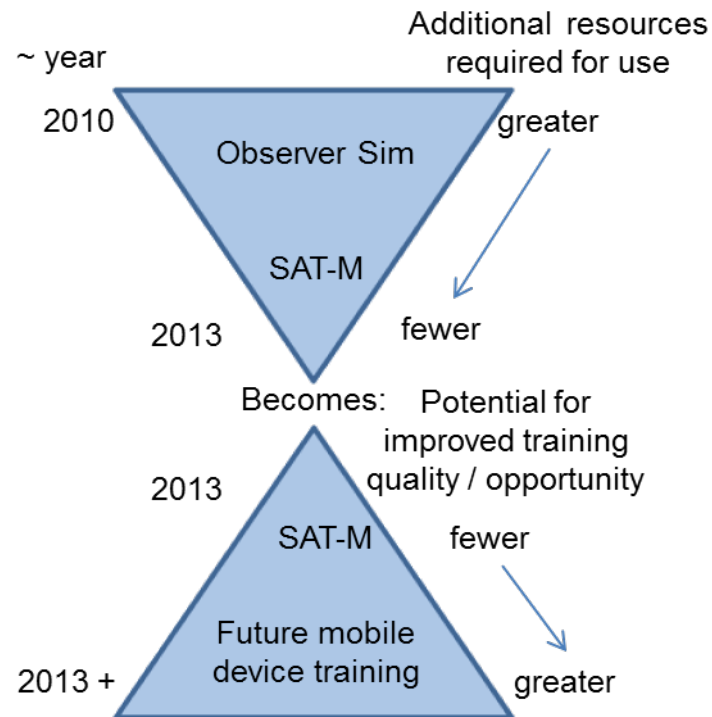


Figure 9. Improvement builds as new technology is adopted into training system design process

- Reuse of previous design process reaps positive results when incorporating new technology
- Tablet training creates new opportunities for end-to-end software delivery and updates
- Additional work in the area of training and simulation design for emerging technologies can produce unexpected advantages, as compared to maintaining the status quo
- Potential of tablet-laptop hybrids to reuse existing software, with minimal refactoring, to provide rapid deployment of tablet system CFF trainers, see the end of Chapter IX
- VEs need to be appropriately aligned with devices to produce desired outcomes, and the use of HARs assessments can aid in the design process



### **C. LIMITATIONS**

SAT-M as built is not production ready, and it will take significant effort to make it so. As reported in Chapter VII there is the possibility of confounding in the experiment. Like any military training, improper instruction leads to negative training, SAT-M needs to be able to provide proper instruction for those times it is used by an untrained user away from an instructor. Tablet systems are not an appropriate solution for every training situation.

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## IX. FUTURE WORK

### A. IMPROVING SAT-M TRAINING SOFTWARE

#### 1. CFF

SAT-M requires further development before it can be introduced for training. Currently it has enough functionality to execute the experiment described in this thesis and some of this apparent functionality is just a façade. For example, when the user brings up the DAGR, a still image appears with a hard coded current location. If the user could move around in the virtual world the DAGR would soon give an invalid location.

The following is a breakdown of what the authors deem necessary for SAT-M to become a functional trainer, as described in the requirements documents and use case scenarios in Chapter IV. There are three tiers. The first tier is the ‘need to haves,’ that which is necessary in order for the software to provide training without the user at risk of developing incorrect live CFF habit patterns. The second tier encompasses the functionality needed for SAT-M to become a viable CFF trainer when used in the presence of a trained instructor. The software would not fulfill all the requirements from Chapter IV, but it would start to realize the potential of tablet VE training. The third tier comprises the ‘nice to haves,’ those features that would make SAT-M a fully functional VE trainer for both the expert and novice user.

##### ***a. Tier One, The Need to Haves***

- SAT-M's virtualized equipment should have a greater level of functionality. This does not have to encompass everything that real equipment does, but should include the function expected during the course of a fire mission. For example, the DAGR does not need to have all of its trouble shooting screens, but it does need to provide present location and allow the user to see how many satellites are being tracked.

- The mission planning should forgo the drop down menus and auto completion, requiring the user to remember or record the pertinent information required to create a six part CFF transmission. The mission planning should also allow the user to execute both grid and polar missions, and make adjustments.
- At this level of development SAT-M does not require more than one scenario, as long as that scenario provides enough diversity to allow for multiple training missions. The scenario needs a range of targets in diverse terrain and at varying distances. SAT-M's current scenario is so trivial that the target set only requires rudimentary skills.

***b. Tier Two, Viable Trainer***

- The virtualized equipment needs to have all the functionality of the real equipment, including idiosyncrasies. For example, the user should be able to set the magnetic variance into the Vector 21b and enter waypoints into the DAGR.
- To assist in mission planning and overall situation awareness SAT-M needs digitized 1:50,000 and 1:100,000 maps of the mission area. Along with this map SAT-M should include a virtual protractor and a pallet of appropriate operational graphics, as well as the ability to easily plot the user's present position, targets locations, fire control measures, and friendly and enemy forces.
- A single high quality scenario can be the backdrop to a diverse set of missions, but eventually the user will become too familiar with it and the training will not be as effective. At this tier SAT-M requires a range of training missions along with the ability to modify them. A scenario run at dusk or night from a different location provides new challenges and training opportunities.

- The mission planning capability should encompass the complete set of CFF missions to include continuous illumination, immediate suppression and suppression of enemy air defenses.

### ***c. Tier Three, Individual Training***

- The intelligent tutoring system is critical for allowing SAT-M to operate as a standalone VE trainer. A great deal of work needs to be done in this area to ensure that the correct information is being collected and relayed back to the user in a useful format. Extraneous information is almost as bad as withholding useful information, as a novice user will have difficulty determining what is important.
- A fully functional scenario creator will allow the user to train in a wide range of missions in diverse environments. It will also enable the instructor to create specific scenarios, allowing the stage to be set for optimal training and the improvement of user weak points.
- Networking is the final component of tier three. This permits users to share scenarios and allows multiple users to execute missions in the same VE. It is a prerequisite for the instructor mode, where the instructor can get a feed from the student's tablet, observing them in real time.

## **2. New Features**

The following two features would greatly increase SAT-Ms ability to provide high quality training.

### ***a. Voice Recognition***

As the number one improvement asked for by the experiment participants, voice recognition would improve the quality of training provided by SAT-M. Speaking the mission, as one does when talking to the fire direction

center (FDC), greatly increase the immersion and transfer of training. Learning to think before speaking and proper communications cadence are skills all Marines must master.

***b. Map Data Downloaded of the Internet***

Multiple technology companies provide high quality satellite imagery and elevation data over the Internet. Google and Apple are examples of two such companies. If SAT-M were able to obtain the licensing required, it could hook into this data and users could create custom scenarios set in almost any location. This has the potential to change SAT-M from a training tool to a mission rehearsal tool.

**3. Other Applications**

Just as the DVTE provides training in both CFF and close air support (CAS) so should SAT-M. The addition of CAS will require including aircraft and air borne ordinance along with the appropriate mission planning tools.

There are multiple websites offering land navigation courses. They require that the user sits sitting at a computer. There are currently no land navigation courses available for mobile devices. By taking advantage of the GPS in tablets SAT-M could change this. Instead of executing the land navigation training in a classroom, SAT-M could provide excellent training in the field, giving real time feedback and advice.

**B. ADDITIONAL EXPERIMENTS**

It is the authors' perception that W2W changes the way the user interacts with the training system. Additional research can be done to determine if that is true and to exactly what degree.

- Does W2W reduce extraneous cognitive load by a measurable amount, and if so by how much?

- Does standing and using W2W keep the user attention for longer than sitting and doing the same tasks with a mouse and keyboard?
- Does W2W appreciably improve a user's psychomotor skills? Is there a measurable difference between using W2W as an input and using a mouse and a keyboard?

### **C. NEW PLATFORM**

The idea behind developing VE training applications for tablets was conceived two years prior to the completion of this thesis, when the authors first arrived at NPS in the summer of 2011. Since that time laptop / tablet hybrid computers have become available. One example is the Intel Ultrabook. The Ultrabook is not technically a product; it is a standard that vendors can follow allowing them to market under the Ultrabook name. Accelerometers and gyroscopes are not currently required by the Ultrabook standard, they are however, recommended (Pinola, 2012).

Ultrabooks run Windows 8, so they should be able to run ObserverSim and FOPCSim. It is possible to add W2W to both programs.

By placing W2W in ObserverSim or FOPCSim the experiment presented in this thesis could be redone, controlling for both software and device. The participants would perform the exact same scenario using the hybrid computer in laptop mode, and then in tablet mode, or in the opposite order. Any difference in preference would be solely due to input modalities. It should also be noted that a W2W enabled ObserverSim or FOPCSim would get the technology to the fleet faster than building SAT-M from the ground up.

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## **APPENDIX A. INTERFACE DESIGN TESTING**

### **A. BACKGROUND**

SAT-M was heavily influenced by the validated processes used to produce earlier CFF VE. The unique input modalities and user expectations of tablet systems were taken into account during the design process. We started with the interface design due to how multi-touch enabled touchscreens change the way users interact with the device. The interface was initially designed using an html mock up and was evaluated in fulfillment of course requirements for CS3004 Human Computer Interfaces. Upon completion of the basic interface design the authors worked with MOVES Institute engineering support team responsible for the development of Delta 3D open source software.

### **B. INTERFACE DESIGN STUDY**

The intent was to create an effective user interface for SAT-M. SAT-M is envisioned as a suite of software that brings the simulation-training center to the Marine. It is an integrated and portable virtual training environment for JFOs and JTACs. Creating a set of fires software that will run on a portable device will allow small unit leaders to greatly increase the quality of the training that occurs in the moments of daily down time. Two sets of instructions were created to standardize the collection of data. The first set, packet A, is the handout provided to the individual administering the usability test. The second set, packet B, is given to the participant. The two sets of instructions work in concert, providing specific instructions to the each of the individuals. The objective of our usability test was to capture qualitative information that provides indication of user satisfaction, interface effectiveness, and interface suitability.

#### **1. Success Criteria**

From our design project we established the information in Table A1 to be our criteria. However, three<sup>(1)</sup> of the criteria can only be evaluated with a fully

functional system, two<sup>(2)</sup> through opinion without a fully functional system, and one<sup>(3)</sup> with our prototype. For the purposes of this project we have evaluated three of the six original success criteria.

SAT-M interface will be successful if it achieves any two of the threshold criteria outlined in the table below. The interface will be highly successful if it meets any of the two objective criteria included in Table A1.

<b>Training Transfer</b>	
<b>Threshold</b>	Positive partial task training for JTAC or JFO mission sets as individuals. <sup>(2)</sup>
<b>Objective</b>	Full task training for JTAC or JFO mission sets as integrated team. <sup>(2)</sup>
<b>Ease Of Use</b>	
<b>Threshold</b>	A qualified JFO or JTAC is able to utilize the software without requiring any assistance. <sup>(3)</sup>
<b>Objective</b>	A qualified JFO or JTAC is able to network multiple devices together and run a multi-person scenario without any assistance. <sup>(1)</sup>
<b>Feedback</b>	
<b>Threshold</b>	Based on system feedback only, an untrained user is able to make correct adjustments to a CFF. <sup>(1)</sup>
<b>Objective</b>	Based on system feedback only, an untrained user is able to conduct a complete CFF. <sup>(1)</sup>

Table A1. Interface design success criteria

## 2. Method

### *a. Target participant population*

The intended users are military personnel and can be broken down into two broad categories, those who have been qualified for controlling of Joint Fires

and everyone else. JTAC's and JFO's characteristics vary from service to service, so for the purposes of the study conducted we focus on United States Marine Corps (USMC) eligibility requirements.

- JTAC. May be a winged aviator, or ground combat arms officer, or combat arms staff non-commissioned officer (E-6 and above).
- JFO. May be officer or enlisted noncommissioned officer (E-3 and above), but must come from the Military Occupational Specialty (MOS) of the indirect fire support agency they will be observing. This means, if the individual is an Artillery JFO, they shall be an artillery officer or enlisted Marine who is in the artillery field.

***b. Proposed demographics***

- Age: 20–40.
- Education: High School diploma—doctorate.
- Gender: Male.
- Cultural: U.S. citizen, though not necessarily naturally.
- Winged naval aviator (no restriction on airframe).
- Combat arms MOS designation (infantry, artillery, tanks).

***c. Actual demographics***

As the system is meant for a trained user, the testing participants were asked three questions, which a JFO should be able to answer. All five of the participants were able to answer the three questions correctly. We believe that the test participants represent the target population well.

- Age: 32–38.
- Education: bachelors—masters.
- Gender: male.
- Cultural: U.S. citizen.
- Winged naval aviators.
- Combat arms MOS designations—artillery.

### **3. Procedures**

#### **a. Tasks**

The testing participants were given five minutes to explore the prototype. If they felt that five minutes was not enough time to get comfortable with the system they were given five more minutes. None of the participants desired the extra five minutes. After getting familiar with the system they were instructed to complete four tasks. The tasks were chosen based on a task analysis conducted during an earlier project for CS3004 coursework. They are typical JFO/JTAC tasks performed during the execution of a mission. The tasks are as follows:

1. Determine the bearing and distance to target.
2. Determine current radio frequency.
3. Determine present position.
4. Determine a 6 digit grid of a point plotted on the map.

Though the prototype is a static set of screen, the required information to accomplish each of the above tasks is embedded in the screens.

### **4. Likert Survey Results**

After completing the tasks the participants filled out a survey consisting of 14 questions. 11 were Likert scale questions. A summary of the results is in Table A2. The specific survey questions can be found in packet B.

Survey Data							
Participant	1	2	3	4	5		
	Strongly disagree	disagree	neutral	agree	Strongly agree	avg	
Question	Q1	5	4	4	5	5	4.6
	Q2	5	5	5	5	5	5
	Q3*	5	5	4	5	5	4.8
	Q4	4	5	3	4	5	4.2
	Q5	5	4	4	4	5	4.4
	Q6	5	5	5	5	5	5
	Q7	5	5	4	4	5	4.6
	Q8	5	5	3	4	4	4.2
	Q9*	5	4	4	5	5	4.6
	Q10	5	5	4	5	5	4.8
	Q11	4	5	2	4	4	3.8
avg	4.5	4.5	3.75	4.5	4.833333		

\* values have been converted to other end of Likert scale due to negative phrasing of the survey question.

Table A2. Likert survey results of interface testing

After completing the Likert portion of the survey the participants answered three open ended questions followed by a structured interview.

#### ***a. Open Ended Questions***

The questions asked what the participants liked the most about the interface, what they liked the least about the interface and if they had any ideas for improvements.

- What did you like the most about the interface?

The participants liked that there were not too many buttons and that it was easy to understand what the buttons do.

- What did you like the least about the interface?

What the participants disliked had more to do with the actual content than the interface. One participant disliked the blurry map; others wanted the devices to be fully functional. Unfortunately, due to the nature of the prototype device functionality could not be implemented.

- Do you have any ideas for improvements?

The best suggestion was to include a notepad so one could manually write calculations and take notes. It was also recommended to include a calculator tool. In addition the protractor was not the easiest to read.

#### ***b. Structured Interview***

The objective of the structured interview was to get the participants creative input. By asking these questions in an interview process it was the hope of the authors that they would get more imaginative results than if the participants just wrote out their ideas.

- In the simulation, what features are missing that you think would improve the quality of training it can deliver.

Ideas to improve the quality of the training varied from using the camera for augmented reality to adding more options for performing fire support.

- Do you see any other potential uses for this sort of simulator beyond CFF and CAS training?

The participants came up with novel ways to use the system; from providing it to non JFO/JTACS to use for device and map training to making a game out of it.

### **5. Discussion**

In Table A2, seven Likert scale questions (Q1, Q3, Q5, Q6, Q7, Q9, and Q10) focused on ease of use and the interface. These seven questions average score of 4.6 indicates that in general the testing participants found the interface to be easy to use. This indicated success in the ease of use criteria category. The lowest score of these questions was, Q5: The Map view interface was intuitive. In this portion of the study many participants had some navigational errors, which could explain the low rating for Q5.

Two questions, Q4 and Q11, were related to training transfer success criteria. These two had the lowest scores, an average of 4.0. It is the opinion of

the authors that this is due to the system being only a prototype. With a fully functional system we expect to have improved results. However, even an average of “agree” means the interface is heading in the right direction.

## **PACKET A**

For the experimenter, ensure that the SAT-M prototype is running on the computer at the top level screen. Then ask the participant the following demographic questions.

---

Service: \_\_\_\_\_ Age: \_\_\_\_\_

Are/were you a qualified JTAC? \_\_\_\_\_ JFO? \_\_\_\_\_

FAC(A)? \_\_\_\_\_

Are/were you an artillery officer, artillery man? \_\_\_\_\_

How long, in years and months, has it been since you last conducted Call For Fire or Close Air Support?

\_\_\_\_\_

Hand the participant the training packet, which consists of **5** pages and instruct them to read and complete the questions on the first page.

The participant will inform you when they have completed reading the pages. Show them the prototype and inform them what the “Map View” button does and that the “home” functionality has been enabled. Then give them 5 minutes to explore the system.

After 5 minutes, ask them:

“Do you feel comfortable enough to take part in the rest of the study?”

If they answer yes, inform them to go to the next page of their packet and complete each task in order.

If they answer no, give them an additional 5 minutes to explore the system and note how much time they take. Extra time taken: \_\_\_\_\_

When they are executing each task you are to time how long it takes them find the appropriate page, collect the appropriate information, note the number of navigational errors, and determine how accurate they were in collecting the information.

After they have completed each task, or five minutes have elapsed, complete the appropriate section on the next pages and have them move onto the next task.

Please do not let the participant see these sheets as the answer to the tasks can be found here.



### Task 1

When instructed to do so, please press the “home button” and then determine the bearing and distance to target #12.

Screen: Vector 21b

Answer: Bearing 060, Distance 6000

Time to Vector 21b screen: \_\_\_\_\_

Time to determine Bearing and Distance: \_\_\_\_\_

Number of navigational errors: \_\_\_\_\_

Was bearing correct? \_\_\_\_\_ Distance correct? \_\_\_\_\_

### Task 2

When instructed to do so, please press the “home button” and then determine what frequency the radio is currently set to.

Screen: Radio Handset

Answer: 036.625

Time to Radio Handset screen: \_\_\_\_\_

Time to determine Frequency: \_\_\_\_\_

Number of navigational errors: \_\_\_\_\_

Was the frequency correct? \_\_\_\_\_

### Task 3

When instructed to do so, please press the “home button” and then determine what your present position is in grid.

Screen: DAGR

Answer: 15T XG 11897E 53935N

Time to DAGR screen: \_\_\_\_\_

Time to determine location: \_\_\_\_\_

Number of navigational errors: \_\_\_\_\_

Was the location correct? \_\_\_\_\_

**NOTE:** Does not have to be in exact form, they can give just 8 digit grid or something similar.

#### **Task 4**

When instructed to do so, please press the “home button” and then determine the 6 digit grid of the point plotted on the map.

Screen: Active Pen

Answer: 845931

Time to Active Pen screen: \_\_\_\_\_

Time to determine grid: \_\_\_\_\_

Number of navigational errors: \_\_\_\_\_

Was the grid correct? \_\_\_\_\_

Once they participant has completed the tasks, inform them to complete the survey found on pages 3 and 4 of training packet. Once they have completed the survey, if they got any of the task question wrong, show them where and how to find the correct information. Then ask them the following questions:

1. In the simulation, what features are missing that you think would improve the quality of training it can deliver.

2. Do you see any other potential uses for this sort of simulator beyond CFF and CAS training?

After they have answered the questions have them read the final paragraph in their training packet. Once they have read it, ask if they have any final question and thank them for their participation.

## **PACKET B**

Welcome to the Supporting Arms Trainer - Mobile (SAT-M) usability analysis. During the next 15–30 minutes you will be asked to work with a prototype of the training simulator. The purpose of the SAT-M is to bring the simulation center to the Marine. We are looking to develop training software that will allow Marines to conduct immersive Call For Fire (CFF) training on a mobile device. You will work with a prototype of the interface. None of the major functionality has been implemented yet. The prototype is a series of linked web pages designed to reflect the program in various states. The data that appears in the various screens and devices will give the appropriate current values.

The information collected during this evaluation is confidential. We are not testing you, we are testing the system. Any difficulties encountered are the systems fault; we need your help to find these problems. Finally, you can stop at anytime Please answer the following questions which are typically known by a joint forward observer.

- (1) How many mils are in a circle?

\_\_\_\_\_

- (2) Name two Methods of target location.

\_\_\_\_\_

\_\_\_\_\_

- (3) A 6 digit grid is accurate to how many meters?

\_\_\_\_\_

Once you have answered the questions please notify the experimenter. You will be instructed to spend five minutes getting familiar with the system. Once the five minutes has passed the experimenter will ask you to conduct a series of short tasks.

### **Task 1**

When instructed to do so, please press the “home button” and then determine the bearing and distance to target #12.

Bearing \_\_\_\_\_

Distance \_\_\_\_\_

**Task 2**

When instructed to do so, please press the “home button” and then determine what frequency the radio is currently set to.

Frequency \_\_\_\_\_

**Task 3**

When instructed to do so, please press the “home button” and then determine what your present position is in grid.

Location \_\_\_\_\_

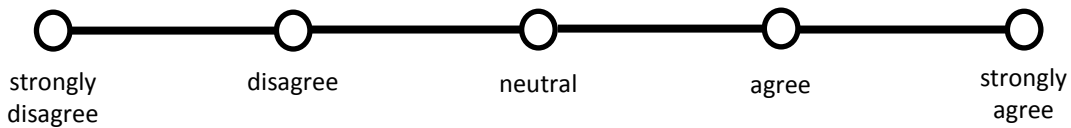
**Task 4**

When instructed to do so, please press the “home button” and then determine the 6 digit grid of the point plotted on the map.

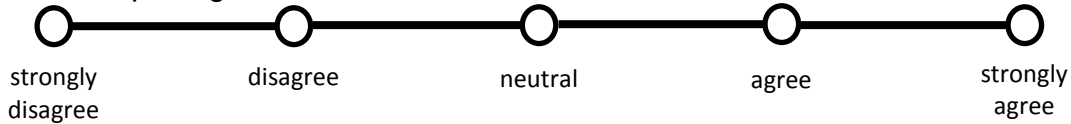
Grid \_\_\_\_\_

You have completed the last task. Thank you. On the following pages you will find 14 survey questions, please take the time to answer them. If you would like, you can refer to the prototype while answering the questions. Once you have answered them please inform the experimenter.

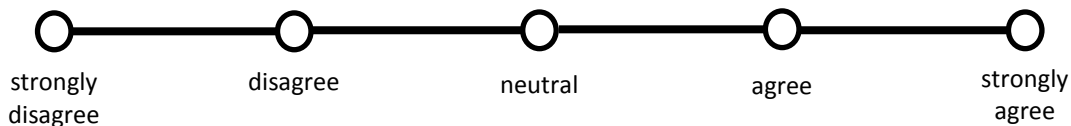
1. The overall interface is intuitive. 7 tier



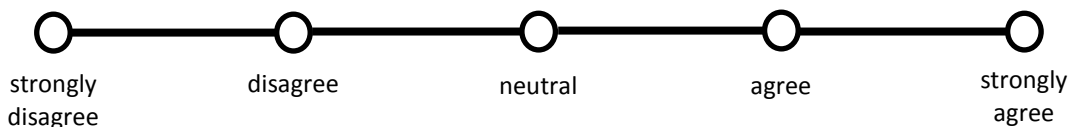
3. It was difficult navigating through the device to find the appropriate information while completing the tasks.



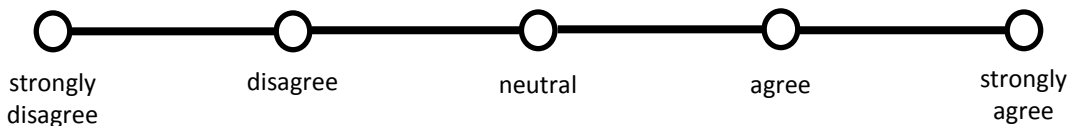
4. A fully implemented system would provide high quality partial task training for a JFO.



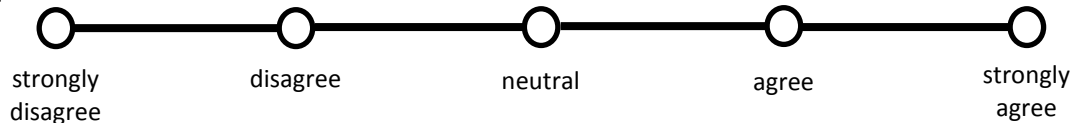
6. The button icons provide intuitive inference of what would happen when they are pressed.



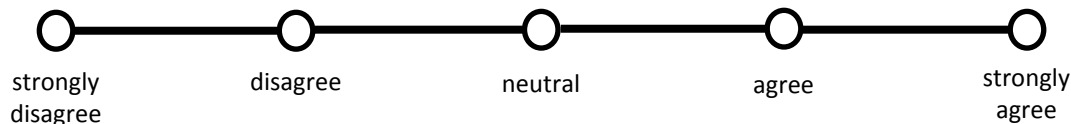
7. It is easy to move though the screens without losing one's place.



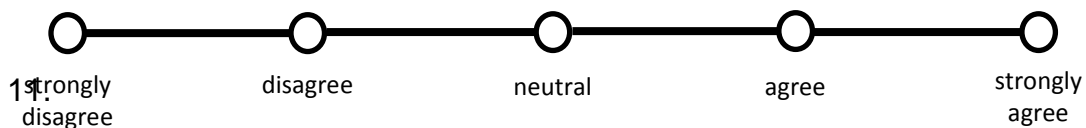
8. Having this software available at my unit would improve my Units ability to perform their mission.



9. It was hard to understand what the buttons did.



10. The 3D view interface was intuitive.



12. Does the device accurately represent the real world physical motion required to conduct the task.

Training with this device on a regular basis will improve my ability to conduct CFF in the field.

12. What did you like the most about the interface?

13. What did you like the least about the interface?

14. Do you have any ideas for improvements?

Thank you for participating in the usability evaluation of Joint Forward Observer Training Suite—Mobile. The time you have taken today will help ensure the lethality and survivability of Marines tomorrow. Based off of the valuable input gathered during this usability evaluation we will redesign the user interface and make recommended changes. As the usability evaluation is ongoing please do not discuss this study with anyone else until Saturday, 10 June, 2012. If you have any questions please ask the experimenter. Again, thank you for your time.

## **APPENDIX B. EXPERIMENTAL DOCUMENTATION**

### **C. RESEARCHERS GUIDE**

#### **1. Chronological Task Listing**

**Recruitment**—(To be completed one week prior to execution of experiment). The researchers will begin recruitment and selection process. E-mails will be distributed soliciting participation. Flyers will be disseminated throughout the NPS campus. When potential participants contact the researchers, they will be informally pre-screened for experience in CFF training. This will enable the researchers to determine initial groupings for IV #1 experience (trained or untrained). (Task duration: ~10 to 15 hours, location: NPS)

**Equipment setup**—(To be completed prior to scheduled arrival of participant) The researcher will prepare the equipment. A tablet device with sufficient battery power will be placed on the laboratory table. Researcher will launch SAT-M software by tapping the appropriate icon. A standard U.S. Marine Corps DVTE laptop will be placed on a desk, a chair will be set in front of it. The researcher should ensure power is being supplied to the laptop, and that a mouse is plugged into the laptop. The researcher will then log into the DVTE and launch the Combined Arms Network software, select and launch Observer Simulator. (Task duration: ~10 minutes, location: NPS, MOVES Lab)

**Consent (page 8–9 below)**—Researcher will provide a hard copy of the NPS consent to research form, participant shall be allowed to read the form, and choose whether to participate or not participate. The participant and researcher obtaining consent will sign the form, which shall be collected by the researcher. (Task duration: ~5 minutes, location: NPS, MOVES Lab)

**Initial exposure period (page 10 below)**—Prior to the conduct of the initial exposure to the device interface the participant will receive a three question survey assessing basic Forward Observer knowledge. The researcher will instruct the participant they are allowed 3 minutes of “freeplay” in order to

familiarize themselves with the interface. All participants will be allowed this opportunity regardless of experience level with software. (Task duration: 5 minutes, location: NPS, MOVES Lab)

**Scenario reset**—The researcher will reinitialize the scenario for the participant. On the tablet running SAT-M the researcher will tap the reset button. On the laptop running Observer Simulator the researcher will navigate to the file menu and select reset scenario. (Task duration: ~30 seconds, location: NPS, MOVES Lab)

**Protocol “A”** (between subjects experimental design)—In this protocol participants will be evenly divided randomly by two our independent variables, training and device. Two phases: Basic CFF process tasks, Execute CFF. Researcher will begin timing the session when worksheet is provided. (Task duration: ~20 minutes, location: NPS, MOVES Lab)

Basic CFF tasks (Tasks will be guided by worksheet):

**Task #1**—Participant is instructed via worksheet to determine their current location through the use of GPS and record that location on the worksheet.

SAT-M (Tablet device)—Using a finger the participant will tap the DAGR icon and record the location information from the device display on their worksheet.

Observer Simulator (Laptop PC)— Using the mouse the participant will navigate to the DAGR icon, click on it and record the location information from the device display on their worksheet.

Researcher will note the elapsed time to complete task, and count any navigational errors made by participant during task execution.

**Task #2**—Participant is instructed to determine the bearing to target for the “technical vehicle” using the lensatic compass and record the information displayed from the virtual compass on their worksheet.



SAT-M (Tablet device)—Using a finger the participant will tap the lensatic compass icon, and then rotate the tablet device until the “technical vehicle” is acquired.

Observer Simulator (Laptop PC)—Using the mouse the participant will navigate to the lensatic compass icon, click the icon and then using the mouse to rotate the view, locate the “technical vehicle”.

Researcher will note the elapsed time to complete task, and count any navigational errors made by participant during task execution.

**Task #3**—Participant is instructed to determine the bearing and distance to a second target, the “tank vehicle”, using the Vector-21b’s and record the information on displayed from the virtual device on their worksheet.

SAT-M (Tablet device)—Using a finger the participant will tap on the Vector-21b icon, and then rotate the tablet device until the “tank vehicle” is acquired. The participant will then use a finger to tap on the bearing and distance icons to generate the data in the display.

Observer Simulator (Laptop PC)—Using the mouse the participant will navigate to the Vector-21b icon, double click the icon and then using the mouse to rotate the view, locate the “tank vehicle”. The participant will then click on the bearing and distance icons to generate the data in the display.

Researcher will note the elapsed time to complete task, and count any navigational errors made by participant during task execution.

**Task #4**—Locate and identify the icon used for generating the CFF 6-line brief.

SAT-M (Tablet device)—Using a finger the participant will visually locate the icon used to generate and send the 6-line CFF, the participant will activate the icon and the researcher will observe that they are complete.

Observer Simulator (Laptop PC)—Using the mouse the participant will navigate to the icon used to generate and send the 6-line CFF, the participant will click the icon and the researcher will observe that they are complete.

Researcher will note the elapsed time to complete task, and count any navigational errors made by participant during task execution. The researcher will reinitialize the scenario for the participant. On the tablet running SAT-M the researcher will tap the reset button. On the laptop running Observer Simulator the researcher will navigate to the file menu and select reset scenario.

**Task #5**—Execute CFF. Using tasks #1, #3, and #4 the participant will generate all required information for a polar, fire for effect, fire mission, and enter it into the CFF mission generation interface.

SAT-M (Tablet device)—Participants will repeat task #1, with the addition of sending the POSREP from the GPS screen by tapping the send POSREP icon. Participants will then repeat task #3. Upon completion of this task participants will repeat task #4, with the addition of entering the 6-line brief. The participant will fill and send line one of the CFF, by selecting “Fire For Effect” in the warning order drop down dialog box, then “Polar” from the location method drop down box. This message will be sent when the participant taps the “checkmark” icon. The participant will then send the direction and distance acquired during task #3 by tapping the “checkmark”. Next, the participant will enter the target description, method of engagement, and method of control information. This is accomplished by selecting quantity of targets, target identification (tank, technical, etc.), level of protection (in open, dug in, etc.), fuse type, and fire command. All tasks are completed by selecting from a drop down dialog under each of the informational areas. When all informational fields are filled, the participant will tap the “checkmark” to send the information. After the message is sent the 6-Line CFF is received by the firing agency. They will respond with a “message to observer”. This message to observer is then “read back” by the participant selecting correct call sign, number of rounds, and target identification number from drop down dialog boxes. The participant then sends

this information back to the firing agency by tapping the “checkmark” box. The firing agency responds when shots are fired, and the participant acknowledges this by tapping the “shot out” icon. After rounds impact, the participant ends the mission by tapping the “end of mission” icon. This concludes the protocol.

Observer Simulator (Laptop PC)—Participants will repeat task #1, with the addition of sending the POSREP from the radio screen by navigating with the mouse to the POSREP entry box and typing the coordinates. Participants will then repeat task #3. Upon completion of this task participants will repeat task #4, with the addition of entering the 6-line brief. The participant will fill and send line one of the CFF, by selecting “Fire For Effect” in the warning order drop down dialog box, then “Polar” from the location method drop down box. This message will be sent when the participant clicks the “K” icon. The participant will then send the direction and distance acquired during task #3 by clicking in the box for each and filling in the information with the keyboard, then click the “K” icon. Next, the participant will enter the target description, method of engagement, and method of control information. This is accomplished by selecting quantity of targets, target identification (tank, technical, etc.), level of protection (in open, dug in, etc.), fuse type, and fire command. All tasks are completed by selecting from a drop down dialog under each of the informational areas. When all informational fields are filled, the participant will click the “K” to send the information. After the message is sent the 6-Line CFF is received by the firing agency. They will respond with a “message to observer”. This message to observer is then “read back” by the participant clicking the “K” icon. After rounds impact, the participant ends the mission by clicking the “end of mission” icon. This concludes the protocol.

**Between subjects survey**—Participants will be provided a short questionnaire that will survey their subjective opinions about the software and device that they have just used to complete the tasks requested. (Task duration: ~5 minutes)

**Protocol “B”**—In this protocol participants will repeat the previous list of tasks in protocol “A”, but the device will be swapped for the one that was not previously used (i.e. in protocol “A” if a tablet was used, then the participant will use the laptop in protocol “B”). (Task duration: ~15 minutes, location: NPS, MOVES Lab)

**Final survey**—Participants will be provided a short questionnaire that will survey their subjective opinions about the software and device that they have just used to complete the tasks requested. It will also solicit comparative information between experiences with the initial device used and the other device. (Task duration: ~5 minutes, location: NPS, MOVES Lab)

**Post experimental tasks**—Primarily consisting of data analysis. We expect to use a two-way ANOVA to analyze results of quantitative testing. The qualitative measures will be described through more pedestrian manners such as mean values. Table 7 in Chapter VI displays the design. (Task duration: ~10 hours, location: NPS)

**D. RESEARCHERS PACKET**

**Virtual environment training experiment**

**(Researcher)  
READ FIRST**

If the participant has no knowledge of CFF provide correct answers to the questions below.
--

SUBJECT Number \_\_\_\_\_

**Call for fire knowledge:**

Please answer the following questions, which are typically known by a Joint Forward Observer.

(1) How many mils are in a circle? \_\_\_\_\_6400\_\_\_\_\_

(2) Name two Methods of target location.

\_\_\_\_\_Grid\_(method using a grid coordinate for location of target)\_\_\_\_\_

\_\_\_\_\_Polar\_(method of using direction and distance from known observers location to the the target)\_\_\_\_

(3) A six digit grid coordinate is accurate to how many meters? \_\_\_\_\_100 meters\_\_\_\_\_

## Protocol “A”

## READ FIRST (RESEARCHER)

Researchers guide, prior to having the participant begin the protocol using the participant worksheet allow them **three minutes** of interface familiarization (freeplay). There is no time limit for Protocol “A”.

Researcher’s guide: After the participant has completed the **Virtual environment training experiment** sheet and is ready to execute Protocol “A” make sure they are seated in front of the DVTE or standing in front of the bench with the Tablet, as appropriate. Provide them with the Protocol “A” sheet.

SUBJECT Number \_\_\_\_\_

### Protocol “A”:

#### Basic CFF tasks:

**Task #1**—Determine current location. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the start time and finish time to complete task, and count any navigational errors made by participant during task execution.

Navigational Errors: \_\_\_\_\_

**Task #2**—Determine the bearing to target for the “technical vehicle” using the lensatic compass. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the start time and finish time to complete task, and count any navigational errors made by participant during task execution.

Navigational Errors: \_\_\_\_\_

**Task #3**—Determine the bearing and distance to the second target, the “tank vehicle”, using the Vector-21b’s. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the start time and finish time to complete task, and count any navigational errors made by participant during task execution.

Navigational Errors: \_\_\_\_\_

**Task #4**—Locate and activate the icon used for transmitting the CFF brief.

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the elapsed time to complete task, and count any navigational errors made by participant during task execution. The researcher will reinitialize the scenario for the participant. On the tablet running SAT-M the researcher will tap the reset button. On the laptop running Observer Simulator the researcher will navigate to the file menu and select reset scenario.

Elapsed time: \_\_\_\_\_ Navigational Errors: \_\_\_\_\_

**Execute CFF brief:**

**Task #5**—Execute CFF

**POSREP** (use self location): (10 digit grid coordinate) .

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Transmission 1:** Method of engagement. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Transmission 2:** Target Location. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Transmission 3:** Description of target, method of engagement, and method of fire and control.

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**MTO:** Read back and acknowledge the message to observer (MTO)

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Shot Over**—For tablet only: Navigational Errors: \_\_\_\_\_

**Select “end of mission”**—Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_ Were rounds 'on target?' Yes / No

**Protocol "A"**

SUBJECT Number \_\_\_\_\_

Inform the participant that protocol "A" is complete and have them complete the questionnaire for protocol "A." While they are completing the questionnaire please note anything specific challenges that the participant had with the system or anything unusual or interesting that the participant did while executing the tasks below.

Once you have completed your note taking and the participant has completed the questionnaire for protocol "A" provide them with the paperwork for protocol "B" and have them switch devices.



**Protocol “B”****READ FIRST (RESEARCHER)**

Researchers guide, prior to having the participant begin the protocol using the participant worksheet allow them **three minutes** of interface familiarization (freeplay). There is no time limit for Protocol “B”.

Researcher’s guide: After the participant has completed the **Protocol “A” qualitative survey** and is ready to execute Protocol “B” make sure they are seated in front of the DVTE of standing in front of the bench with the Tablet, as appropriate. Provide them with the Protocol “B” sheet.

SUBJECT Number \_\_\_\_\_ What device did you use during protocol “A”? Laptop / Tablet

**Protocol “B”:**Basic CFF tasks:

**Task #1**—Determine current location. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the start time and finish time to complete task, and count any navigational errors made by participant during task execution.

Navigational Errors: \_\_\_\_\_

**Task #2**—Determine the bearing to target for the “technical vehicle” using the lensatic compass. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the start time and finish time to complete task, and count any navigational errors made by participant during task execution.

Navigational Errors: \_\_\_\_\_

**Task #3**—Determine the bearing and distance to the second target, the “tank vehicle”, using the Vector-21b’s. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the start time and finish time to complete task, and count any navigational errors made by participant during task execution.

Navigational Errors: \_\_\_\_\_

**Task #4**—Locate and activate the icon used for transmitting the CFF brief.

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Researcher will note the elapsed time to complete task, and count any navigational errors made by participant during task execution. The researcher will reinitialize the scenario for the participant. On the tablet running SAT-M the researcher will tap the reset button. On the laptop running Observer Simulator the researcher will navigate to the file menu and select reset scenario.

Elapsed time: \_\_\_\_\_ Navigational Errors: \_\_\_\_\_

**Execute CFF brief:**

**Task #5**—Execute CFF, Start time: \_\_\_\_\_

**POSREP** (use self location): (10 digit grid coordinate) .

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Transmission 1:** Method of engagement. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Transmission 2:** Target Location. Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Transmission 3:** Description of target, method of engagement, and method of fire and control.

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**MTO:** Read back and acknowledge the message to observer (MTO)

Start time: \_\_\_\_\_ Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_

**Shot Over**—For tablet only: Navigational Errors: \_\_\_\_\_

**Select “end of mission”**—Finish time: \_\_\_\_\_

Navigational Errors: \_\_\_\_\_ Were rounds ‘on target?’ Yes / No

**Protocol “B”**

SUBJECT Number \_\_\_\_\_

Inform the participant that protocol “B” is complete and have them complete the questionnaire for protocol “B.” While they are completing the questionnaire please note anything specific challenges that the participant had with the system or anything unusual or interesting that the participant did while executing the tasks below.

Once the participant has completed the questionnaire for protocol “B” provide them with the **Post-experiment Demographic Questionnaire**.

## **E. PARTICIPANT PACKET**

### **Naval Postgraduate School Consent to Participate in Research**

**Introduction.** You are invited to participate in a research study entitled Virtual Environment Training on Mobile Devices, Supporting Arms Trainer-Mobile. United States Marine Corps 2012 Science and Technology Plan identifies a critical Training and Education gap in T&E STO-6: Warrior Simulation: “Marines need to train as they would fight as small units, particularly for dismounted operations. However, live training resources, facilities, ranges and training areas are limited. Simulation capabilities are needed to provide real-time effects and realistically engage the senses during challenging, rapidly reconfigurable scenarios to increase small units’ opportunities to train when they do not have access to live resources. Develop capabilities to realistically simulate munitions (friendly and enemy) effects within live, virtual, and constructive training environments. Develop the ability to stimulate operational equipment used in live training environments from virtual or constructive environments, to improve the capability of simulations to augment and enhance live training opportunities and to reinforce realistic training using actual equipment as often as possible in conjunction with simulators and simulations”. The purpose of the research is to investigate mobile devices as a platform for training simulations as it aligns with the above outlined science and technology objective.

Procedures.

- Consent will be solicited.
- Experimental procedures will include standard Call For Fire (CFF) tasks, such as determine self-location, determine bearing and distance to a target, and generate a standard CFF brief.
- The expected duration in total is approximately 45 minutes:
  - Consent (five minutes)
  - CFF knowledge test (five minutes)
  - Protocol A (15 minutes)
  - Survey (five minutes)
  - Protocol B (10 minutes)

- Final questionnaire and debrief (five minutes)
- Participants will be video recorded to ensure accurate data collection.
- We expect a minimum of 32 participants in the research, and anticipate as many as 64.
- All subjects will be exposed to the same experimental conditions.

**Location.** The interview/survey/experiment will take place at the MOVES Institute, Naval Postgraduate School in the laboratory.

**Cost.** There is no cost to participate in this research study.

**Voluntary Nature of the Study.** Your participation in this study is strictly voluntary. If you choose to participate you can change your mind at any time and withdraw from the study. You will not be penalized in any way or lose any benefits to which you would otherwise be entitled if you choose not to participate in this study or to withdraw. The alternative to participating in the research is to not participate in the research.

**Potential Risks and Discomforts.** The potential risks of participating in this study are: possibility of eye, hand, and arm strain typically associated with normal laptop or tablet use. There is a potential for breach of confidentiality.

**Anticipated Benefits.** Anticipated benefits from this study include advances in virtual training environments. This will enable DoD to provide unique and innovative new interfaces for the user (military trainee) as well as new methods for training and educational material delivery. You will not directly benefit from your participation in this research.

**Compensation for Participation.** No tangible compensation will be given.

**Confidentiality & Privacy Act.** Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research record confidential but total confidentiality cannot be guaranteed. All records will be stored securely at the MOVES institute in locked storage container. Access to records will only be allowed to the Primary Investigator and student researchers whom have completed required CITI training. All personally identifiable information will be cleansed, and all participants will remain anonymous. All data and consent will be forwarded to the IRB for long term storage.

**Points of Contact.** If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, Dr. Joseph Sullivan, 831–656–7562, [sullivan@nps.edu](mailto:sullivan@nps.edu). Questions about your rights as a research subject or any other concerns may be addressed to the Navy Postgraduate School IRB Chair, Dr. Larry Shattuck, 831–656–2473, [lgshattu@nps.edu](mailto:lgshattu@nps.edu).

**Statement of Consent.** I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights.

Participant's Signature

Date

Researcher's Signature

Date

### **Virtual environment training experiment**

**(Participant)  
READ FIRST**

The following experiment and questionnaire are completely confidential. Nothing you do or answer will be related back to you in any manner. Thank you for your participation. Please answer all of the questions below and hand to the proctor when you reach "STOP HERE." You may ask the proctor questions at any time. There is no time limit.

SUBJECT Number \_\_\_\_\_

Have you ever conducted Call for fire (real or simulated)? Yes / No

Have you ever attended a school dedicated to CFF or combined arms? Yes / No

#### **Call for fire knowledge:**

Please answer the following questions, which are typically known by a Joint Forward Observer.

(1) How many mils are in a circle? \_\_\_\_\_

(2) Name two Methods of target location.

\_\_\_\_\_

\_\_\_\_\_

(3) A six digit grid coordinate is accurate to how many meters?

\_\_\_\_\_

Once you have answered the questions please notify the experimenter. You will be allowed three minutes to get familiar with the system. Upon completion of this familiarization period the proctor will provide a series of short tasks.

**"STOP HERE"** Please get the Proctor's attention to continue

**Protocol “A”**

**READ FIRST (PARTICIPANT)**

SUBJECT Number \_\_\_\_\_

The following experiment is confidential. Nothing you do or answer will be related back to you in any manner. Thank you for your participation. There is no time limit.

Please spend the next three minutes getting familiar with the device and software. The proctor will inform you when three minutes has expired.

Basic CFF tasks:

**Task #1**—Determine your current location using GPS and record the location.

Your current location: \_\_\_\_\_.

**Task #2**—Locate the “technical vehicle” (pick-up like truck) and determine the bearing to it using the lensatic compass. Record the information displayed on the virtual compass below.

Bearing to “technical vehicle”: \_\_\_\_\_.

**Task #3**—Locate and determine the bearing and distance to the second target, the “tank vehicle”, using the Vector-21b’s, sometimes labeled as ‘rangefinders,’ and record the information on display.



Icon for bearing



Icon for range

Bearing to “tank vehicle” \_\_\_\_\_ Distance to “tank vehicle” \_\_\_\_\_

**Task #4**—Locate and activate the icon used for transmitting the CFF brief.

Briefly describe the icon: \_\_\_\_\_

Please turn this sheet over and follow the instructions on the other side.

### **Execute CFF brief:**

You will now generate and execute a CFF, the target is the **tank** you located in task #3.

#### **Task #5—Execute CFF.**

First: Transmit a POSREP (Position Report) to the FDC (Fire Direction Center) using self-location.

Once the POSREP has been transmitted you are ready to create and transmit the three transmissions for the CFF.

**Transmission 1:** (if applicable to your device) select - Agency: “kilo btry”, Name: “Obs”, Warning Order: “fire-for-effect”, Location Method: “polar”

Transmit (✓ or K)

**Transmission 2:** Fill in the Polar Direction and Distance to the target, skip the U/D dialog..

Transmit (✓ or K)

**Transmission 3:** Select the target quantity, type and cover (I/O stands for “in the open”). Then select the following:

Method of engagement (select “HE/Quick”)

Method of Control (select “when ready”)

Transmit (✓ or K)

**MTO:** You will receive a message to observer (MTO) from the FDC. You will need to ‘read it back’ precisely as they sent it to you. Fill in your response appropriately.

Transmit (✓ or K)

**Shot Out:** You may be asked to respond to this radio call with: **Shot Over**

Observe target for rounds impact

Select “**end of mission**”



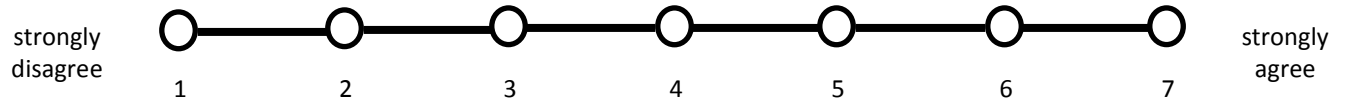
### READ FIRST

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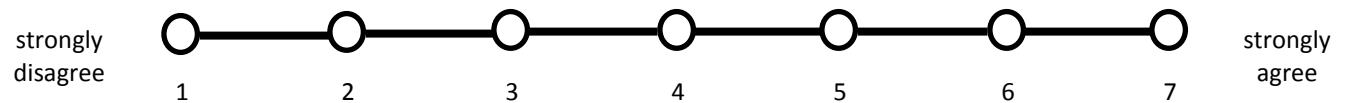
SUBJECT Number \_\_\_\_\_

#### Protocol "A" qualitative questionnaire: (a "4" means no strong opinion)

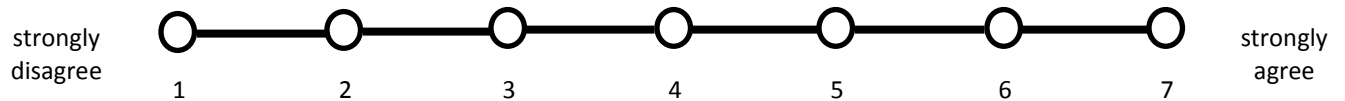
1. Training with this device on a regular basis will improve my ability to conduct CFF in the field.



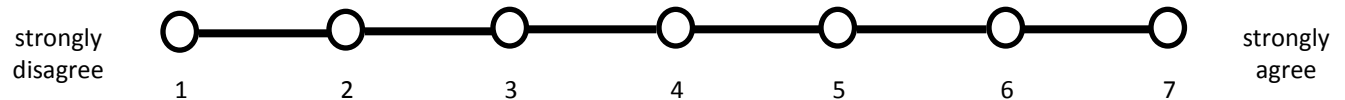
2. It was difficult navigating through the device to find the appropriate information while completing the tasks.



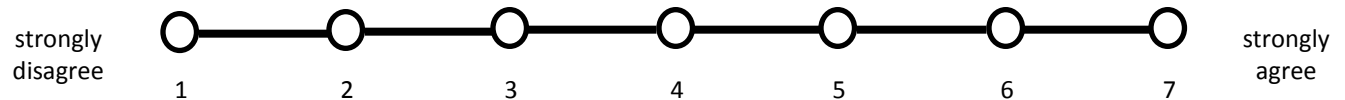
3. The real world physical actions and conducting a task in the virtual environment are the same.



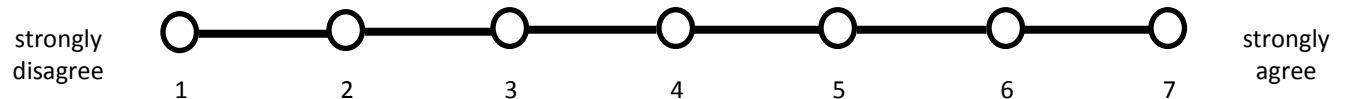
4. The button icons provide intuitive inference of what would happen when they are pressed.



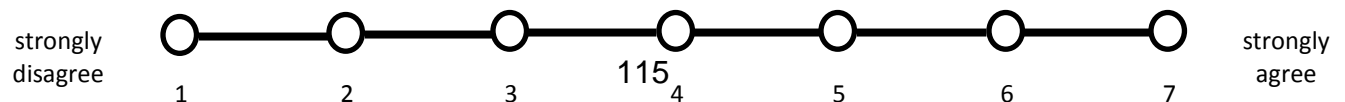
5. It is easy to move through the screens without losing one's place.



6. Having this software available at my unit would improve my Units ability to perform their mission.



7. It was hard to understand what the buttons did.



8. The 3D view interface was intuitive.

strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree
	1	2	3	4	5	6	7	

9. The device accurately represents the real world physical motion required to conduct the task.

strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree
	1	2	3	4	5	6	7	

10. The overall interface is intuitive.

strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree
	1	2	3	4	5	6	7	

11. Please provide any additional comments about your experience with the device here:

**"STOP HERE"** Please get the Proctor's attention to continue

**Protocol “B”****READ FIRST (PARTICIPANT)**

SUBJECT Number \_\_\_\_\_

What device did you use during protocol “A”? Laptop / Tablet

Please spend the next three minutes getting familiar with the device and software. The proctor will inform you when three minutes has expired.

**Basic CFF tasks:****Task #1**—Determine your current location using GPS and record the location.

Your current location: \_\_\_\_\_.

**Task #2**—Locate the “technical vehicle” (pick-up like truck) and determine the bearing to it using the lensatic compass. Record the information displayed on the virtual compass below.

Bearing to “technical vehicle”: \_\_\_\_\_.

**Task #3**—Locate and determine the bearing and distance to the second target, the “tank vehicle”, using the Vector-21b’s, sometimes labeled as ‘rangefinders,’ and record the information on displayed.



Icon for bearing



Icon for range

Bearing to “tank vehicle” \_\_\_\_\_ Distance to “tank vehicle” \_\_\_\_\_

**Task #4**—Locate and activate the icon used for transmitting the CFF brief.

Briefly describe the icon: \_\_\_\_\_

Please turn this sheet over and follow the instructions on the other side.

### **Execute CFF brief:**

You will now generate and execute a CFF, the target is the **tank** you located in task #3.

#### **Task #5—Execute CFF.**

First: Transmit a POSREP (Position Report) to the FDC (Fire Direction Center) using self-location.

Once the POSREP has been transmitted you are ready to create and transmit the three transmissions for the CFF.

**Transmission 1:** (if applicable to your device) select - Agency: “kilo btry”, Name: “Obs”, Warning Order: “fire-for-effect”, Location Method: “polar”

Transmit (✓ or K)

**Transmission 2:** Fill in the Polar Direction and Distance to the target, skip the U/D dialog.

Transmit (✓ or K)

**Transmission 3:** Select the target quantity, type and cover (I/O stands for “in the open”). Then select the following:

Method of engagement (select “HE/Quick”)

Method of Control (select “when ready”)

Transmit (✓ or K)

**MTO:** You will receive a message to observer (MTO) from the FDC. You will need to ‘read it back’ precisely as they sent it to you. Fill in your response appropriately.

Transmit (✓ or K)

**Shot Out:** You may be asked to respond to this radio call with: **Shot Over**

Observe target for rounds impact

Select “**end of mission**”

### READ FIRST

The following experiment and questionnaire are completely confidential. Nothing you do or answer will be related back to you in any manner. Thank you for your participation. Please answer all of the questions below and hand to the proctor when you reach "STOP HERE." You may ask the proctor questions at any time. There is no time limit.

SUBJECT Number \_\_\_\_\_

#### PART III:

#### Protocol "B" qualitative questionnaire: (a "4" means no strong opinion)

1. Training with this device on a regular basis will improve my ability to conduct CFF in the field.

strongly disagree    ☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5    ☐ 6    ☐ 7    strongly agree

2. It was difficult navigating through the device to find the appropriate information while completing the tasks.

strongly disagree    ☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5    ☐ 6    ☐ 7    strongly agree

3. The real world physical actions and conducting a task in the virtual environment are the same.

strongly disagree    ☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5    ☐ 6    ☐ 7    strongly agree

4. The button icons provide intuitive inference of what would happen when they are pressed.

strongly disagree    ☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5    ☐ 6    ☐ 7    strongly agree

5. It is easy to move through the screens without losing one's place.

strongly disagree    ☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5    ☐ 6    ☐ 7    strongly agree

6. Having this software available at my unit would improve my Units ability to perform their mission.

strongly disagree    ☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5    ☐ 6    ☐ 7    strongly agree

7. It was hard to understand what the buttons did.

strongly disagree    ☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5    ☐ 6    ☐ 7    strongly agree

8. The 3D view interface was intuitive.

strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree
	1	2	3	4	5	6	7	

9. The device accurately represents the real world physical motion required to conduct the task.

strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree
	1	2	3	4	5	6	7	

10. The overall interface is intuitive.

strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	strongly agree
	1	2	3	4	5	6	7	

The questionnaire continues on the next page.

**Protocol “B” qualitative questionnaire continued**

Circle one:

11. Which device was more intuitive to use:

Laptop / Tablet

12. If the software on both devices were about equivalent I would prefer to use:

Laptop / Tablet

13. If each device had the same feature set I would prefer to use:

Laptop / Tablet

14. This device is more convenient to train with:

Laptop / Tablet

15. Please provide any additional comments that you think would be useful to researchers about your experience with the devices here:

**"STOP HERE"** Please get the Proctor's attention to continue

### READ FIRST

The following experiment and questionnaire are completely confidential. Nothing you do or answer will be related back to you in any manner. Thank you for your participation. Please answer all of the questions below and hand to the proctor when you reach "STOP HERE." You may ask the proctor questions at any time. There is no time limit.

SUBJECT Number \_\_\_\_\_

#### PART IV:

#### **Post-experiment Demographic Questions:**

1. What is your primary military specialty? (Provide name of specialty)

\_\_\_\_\_

2. Have you been school-trained in conducting artillery call for fire (CFF)?

YES NO

3. Have you held the billet of or performed the duties of a forward observer?

YES NO

4. Have you held the billet of or performed the duties Artillery Liaison Officer?

YES NO

5. Have you conducted artillery call for fire with live rounds? YES NO

5.a If so, approximately, how long has it been since the last time you conducted live CFF?

\_\_\_\_\_

6. For how many hours do you use a computer on a daily basis?

\_\_\_\_\_

7. For how many hours do you use a tablet device on a daily basis?

\_\_\_\_\_

9. Have you ever used a virtual environment for training or entertainment (i.e. first person shooter games, VBS2, America's Army, etc.)

YES NO

10. Have you ever used a virtual environment for forward observer training (i.e. TSFO, FOPC, CAN, etc.)?

YES NO



a. What was the name(s) of the virtual environment(s)?

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

11. When you were at your most proficient with CFF, how would you rate that proficiency?

Untrained	Novice	Average	Advanced	Expert
-----------	--------	---------	----------	--------

12. Given many duties of a forward observer are perishable, how would you rate your current proficiency in call-for-fire?

Untrained	Novice	Average	Advanced	Expert
-----------	--------	---------	----------	--------

13. During the course of your military career, while you were deployed or in any other field environment:

a. Did you or your unit have a computer available for general use? YES NO

b. Did you or your unit have a tablet device (iPad or andriod) available for use?

YES NO

**"STOP HERE"** Please get the Proctor's attention to continue

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